Resource Allocation in the Department of Defense

A Case Study of Army Aviation Maintenance

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PREFACE

This report was prepared as part of Rand's Defense Manpower Studies Program, sponsored by the Office of the Assistant Secretary of Defense (Manpower, Reserve Affairs, & Logistics)—OASD(MRA&L). The purpose of this program is to develop broad strategies and specific problem-oriented research.

Using the planning and management processes in Army aviation maintenance, we examine how DOD adjusts resource requirements in response to input price changes. The report is based on an extensive literature survey and several hundred interviews conducted during 1977-1979. Because defense activities are dynamic, many of the specific problems in Army aviation maintenance have changed since the period of this report. For example, industrial funding, a topic of great importance to aviation maintenance today, was much less important during the period we addressed and receives little attention here. The study does not seek to solve specific problems in Army aviation maintenance, however, or even to focus exclusively on Army aviation maintenance itself. It addresses a problem that has persisted over the entire period since World War II—DOD's reluctance to recognize changing input prices and respond adequately. A study going back a few years should place the specific problems of Army aviation maintenance in perspective as illustrations or manifestations of this deeper problem.

The report aims to provide a better understanding of how DOD's planning and management processes work, to provide a foundation upon which future work can build to define policy options that improve these processes. We do not offer specific policy recommendations.

The report should be of greatest interest to defense planners and analysts. It will act as a primer for analysts just now beginning to study how DOD makes resource decisions. In this role, it emphasizes the utility of formal analytic tools in understanding existing decision processes. For planners and analysts more familiar with specific activities within DOD, the report argues that unless problems are placed in a broader context, the specific solutions chosen to deal with them are unlikely to take hold.

Frank Camm directed the study and collected a great deal of the national-level data. Joyce Davidson collected all of the installation

data. Geraldine Walter collected all of the depot data. Christopher Worthing was primarily responsible for data on in-the-field units. Frank Camm integrated these data and wrote the final report.

SUMMARY

DOD's reaction to price changes involves the use of a complex array of management and planning processes. To understand how each process reacts and the way these processes relate to one another, we selected one defense activity, Army aviation maintenance, for detailed investigation. The selection of so narrowly defined an activity limits our ability to make general statements about DOD, but many of our observations carry over to DOD as a whole; most of the processes we observed were created to meet DOD demands and others are typical of DOD's approach to resource problems.

Information on how DOD reacts to changes in its cost environment is of particular interest because empirical evidence on the period since World War II suggests that DOD has adjusted very little to the dramatic changes in capital and labor costs. Our case study illustrates resource management procedures that are typical of other DOD activities and suggests that the observed response is the result of the cumbersome and sluggish processes DOD uses for resource allocation. Five characteristics of Army aviation resource management in the mid 1970s support this conclusion.

First, Army maintenance personnel with whom we spoke typically think of capital-labor substitution in terms of the design of new aircraft with reduced requirements for maintenance manhours. Although this is an important source of substitution, it is by no means the only one. We found innumerable other opportunities among inputs in maintenance shops that were often exploited by local managers in response to resource shortages but not officially recognized or sanctioned in Army planning. These opportunities are multiplied by substitutability among maintenance outputs and among resources in different activities. The high level of uncertainty in military maintenance creates opportunities for substitution as well.

Second, cost information and analysis systems in the Army were directed more toward formulation of budgets for predetermined resource mixes than toward comparison of the costs of alternative mixes. This was particularly troublesome at the local level. Existing cost analysis could not accommodate the budgeting and pricing complexities that make up a local manager's operating environment and was of little use to him and did not earn his respect. In the absence of systems that allow cost comparisons and to support local decisionmak-

ing, defense managers will have to rely on informal, crude alternatives to determine how to react to cost changes.

Third, although Army aviation attempted to impose central control on maintenance and other activities, it did not provide information systems that informed top-level managers of subtle changes in the activity's environment. Most of the systems in the mid 1970s suffered from biased reporting, and many experienced inconsistent application. Cost data in general had a low priority. As a result, major decisions continued to emerge from a consensus of experienced managers who typically drew more heavily on their experience than on the questionable data available on current events. Such a decision process was inherently conservative.

Fourth, wartime was considered of paramount importance with little attention paid to the possible wartime setting. Managers gave less attention to peacetime than to wartime concerns, spent less time responding to peacetime changes, and were not clear on such issues as wartime requirements. If more attention were given to defining the continuity between wartime and peacetime scenarios, peacetime data could be used to analyze resource decisions that must necessarily be made with war in mind. Knowledge of scarcity management during wartime could promote the use of cost systems, budgets, and prices as decisionmaking tools and not just as accounting devices.

A fifth and final observation is that existing resource allocation processes were not designed to allow continuous, spontaneous adjustment to DOD's cost environment, for the simple reason that costs were not considered of major importance. If wartime was primal, why respond to changes in the peacetime environment? In particular, if cost reduction was not an object in wartime, why give attention to peacetime operating costs? Further, nobody knew what the next war would look like, so past experience in war was probably as valid as current experience in peace. When information systems did not behave as intended, then, what was really gained by expending command emphasis to get them working? In the end, substitution was best pursued through new aircraft design, and we did not need extensive management information systems to design aircraft.

These assumptions all fit together, and the world view they sustain will not collapse until the weaknesses in the basic premises underlying it are explained and operational alternatives are designed. This study attempts to identify weaknesses in the current world view. Further progress will require attention to specific behavioral relationships within DOD and to control systems explicitly designed to be compatible with these relationships.

ACKNOWLEDGMENTS

The material presented in this report is based on several hundred interviews conducted primarily in the Office of the Army Deputy Chief of Staff for Logistics (DA DCSLOG), the Army Materiel Development and Readiness Command (DARCOM), the Army Forces Command (FORSCOM), and the Army Training and Doctrine Command (TRADOC). We wish to thank all those in Army aviation maintenance who provided us with information and assistance.

Earlier drafts have also benefited from the comments of Brad Bergmann of OSD (MRAL), Steven Cauley of the University of New Mexico, Steven Chapel of the Electric Power Research Institute, Richard Cooper of Coopers and Lybrand, Thomas McNaugher of The Brookings Institution, and Robert Roll of Scientific Applications, Inc. We are also grateful for the comments of Rand colleagues Cheryl Cook, Christopher Harz, James Hosek, Robert Paulson, and Robert Shishko. Laura Goeglein, Helen Loesch, and Ellen McCann prepared the numerous drafts underlying this report. Any errors of fact or interpretation that remain are the responsibility of the authors.

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I. INTRODUCTION

During a period of growing demands for defense services and growing scarcity of resources with which to provide them, it is useful to ask whether there are any obvious places were we can squeeze more from the resources now committed to national defense. Or can we identify defense services that require fewer resources to provide—by whatever definition—a level of security equivalent to what we experience today? For example, there is strong evidence that, given the current relative costs of capital and labor services in the United States, the Department of Defense (DOD) uses far too much labor to provide national security services. Changes in military technology and organization that reduce labor use could allow us to make a large increase in the level of national security without changing military spending.[1] Why hasn't DOD made such changes?

This report hypothesizes that resource allocation processes within DOD are not designed to detect and respond to changes in relative input prices. In the large, this suggests that DOD has difficulty responding to secular changes in the relative prices of the inputs it purchases from the civilian economy, helping explain why it uses so much labor. In the small, within individual activities, it suggests that DOD cannot easily detect differences between the values and costs of inputs at the margin. Further, substantial opportunities for resource savings would exist even if relative input prices had not shifted in the economy as a whole. DOD's difficulties in responding to external changes and detecting internal opportunities probably stem from similar sources.

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[1]Cooper and Roll (1974) found that, over the postwar period, DOD's ratio of capital to labor changed very little while that in the economy as a whole rose dramatically. DOD's lack of response may have reflected an efficient use of resources, but that is unlikely. For DOD's use of resources to be efficient, one of three conditions must hold. First, DOD would have had to have a fixed proportions technology. Such a technology is rarely observed elsewhere on such a large scale; evidence in Sec. III suggests that it does not apply in DOD either, certainly not in the long run. Second, technical change biased toward saving capital would have had to take place since World War II at a pace just sufficient to offset substitution away from labor. This explanation is not only counterintuitive but has no empirical support inside or outside DOD. Third, DOD would have had to start the period with too much capital and simply maintained that capital as prices adjusted to make it more cost effective to hold this capital. This is the least intuitive and convincing possibility of all. If instead DOD's aggregate production technology is similar to that for the economy as a whole, DOD's overuse of labor imposes a cost of about $6 billion a year. For an explanation of how this figure was derived, see Appendix F.

We examine this hypothesis in the specific context of the allocation of resources in the provision of Army helicopter maintenance during the late 1970s. Preliminary discussions revealed that resource allocation processes in DOD are complex. Restricting our analysis to a specific activity allows a comprehensive view of all the processes that contribute to resource decisions in that activity. Army helicopter maintenance is of interest for a number of reasons. First, the Army uses a more decentralized management system than do the other services, raising control problems likely to play a key role in adjusting the allocation of resources. Although helicopters are very different from fixed-wing aircraft, they do share enough similarities to allow cross service comparisons.[2] This report does not attempt such comparisons, but it does provide data and a methodology that could contribute to such a comparison.

Maintenance is more amenable to analysis than many other defense activities. It has definable and potentially measurable outputs and many other parallels with activities conducted in the private economy. At the same time, it is not atypical of many "commercial-industrial" activities that account for a major portion of DOD's operating and investment expenditure.[3] Our use of historical data rather than data on current operations should help emphasize that our primary concern is the general issue of resource allocation in DOD and not the specific problems we happened to observe in Army aviation maintenance during 1977-1979. Although many of the specific problems have surely changed, we are confident that the basic modes of operation and planning that we observed have continued to the present.

To keep things manageable, we put three additional restrictions on the study. First, we studied resource allocation only in the maintenance of existing helicopter types. Changing the input mix through the development of new aircraft is well known and has generated an extensive literature.[4] We examined opportunities that can be exploited without the long lead time associated with the development of new aircraft. Second, to conserve our own resources, we studied resource allocation only as it affects helicopters in the U.S. Army Forces Command (FORSCOM). This is the single largest "owner" of

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[2]Although the Army maintains a fixed-wing capability, it is not so important as that associated with its helicopters. References to Army aviation in this study will always be references to helicopters.

[3]By itself, maintenance accounted for $26 billion in the FY 1976 DOD operating budget. (U.S. Army Command and General Staff College, 1976, p. 6-5.)

[4]Reddick (1975), a study of the opportunities for redesigning components in Army helicopters with high operating costs, is a good example and bears directly on our area of interest.

aircraft in the Army; resource allocation processes that affect FORSCOM aircraft tend to affect aircraft elsewhere in the Army in a similar way. Finally, we studied only peacetime resource allocation processes. These, of course, cannot be studied without ultimately addressing wartime needs, but the focus of our attention is peacetime.

In sum, an analysis of Army helicopter maintenance is likely to raise most of the issues important to the study of resource allocation in DOD. Our study revealed an awkward, unresponsive resource allocation process in which change is often costly and difficult. Such problems, acknowledged by many Army personnel, are not unique to the Army. We do not generally depict the problems as extending beyond Army aviation maintenance because we do not have primary data outside this activity, but considerable evidence points to similar problems throughout DOD.[5]

Section II reviews some basic production concepts that we use to examine Army aviation maintenance. It defines maintenance as a production activity and relates the economist's view of input substitution to resource allocation in the Army. Section III develops a mid-term perspective for resource allocation in which the Army designs aviation maintenance organizations. It concentrates on the design of military organizations and suggests that costly information systems and a doctrine that emphasizes design for wartime without concern for current costs reinforce one another to assure that military organizations pay little attention to changing relative input prices. Section IV develops the short-term perspective in which operators produce maintenance services within organizations with fixed sets of inputs. It emphasizes that local maintenance supervisors appear quite responsive to perceived changes in relative input prices but that their perceptions do not mirror the input prices that should interest the Army. It suggests that a more appropriate view of costs in the Army could help local supervisors manage the shortages that dominate their concerns about resources. It could also assist planners in using data on actual peacetime experience to design organizations for wartime. Section V summarizes the report's five conclusions, and the appendixes provide backup data.

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[5]See, for example, Rice (1979).

II. PRODUCTION AND COST IN ARMY HELICOPTER MAINTENANCE

Army helicopter maintenance uses a variety of inputs to produce a variety of outputs; it is a production activity. From this perspective, it is very much like other service activities in the U.S. economy. Because it is typically not provided in a free market environment and exists mainly to support military combat missions in wartime, its character as a production activity is often overlooked.

THREE FORMS OF ARMY MAINTENANCE ACTIVITIES

In 1977 and 1978, the Army pursued aviation maintenance in three types of shops: depots, installations, and "in-the-field" military units. As Fig. 1 suggests, these were related to one another in a well-defined way.[1] The depot performed the most difficult tasks, requiring highly skilled technicians and highly specialized capital equipment. The installation and military aviation intermediate maintenance (AVIM) units performed less difficult repair tasks and provided direct support to the lowest level of maintenance, performed in aviation unit maintenance (AVUM) shops.[2]

Although these shops coordinated their activities with one another and engaged in a substantial amount of exchange of supply items, maintenance tasks, information, and money, each was a distinctly separate activity, organized and run under its own guidelines. Depots are staffed by civilian government employees. Their design, staffing levels, budgets, and performance were supervised by the U.S. Army Development and Readiness Command (DARCOM). Each one was different in its mission and design. Installation shops are also staffed by civilian government employees. In the continental United States (CONUS), they were all part of the U.S. Army Forces Command (FORSCOM).[3] It supervised their design, staffing levels, budgets, and

[1]The Maintenance Allocation Chart (MAC) laid these relationships out in extraordinary detail for each type of Army equipment. Appendix A contains a glossary of acronyms used in this report.

[2]This "three-category" maintenance concept developed out of aviation experience in Vietnam. It was being phased in to replace the "four-category" concept typical of other Army activities during the late 1970s. For details, see Appendix B.

[3]Overseas, they were supervised by the appropriate major commands within whose territory they lay.

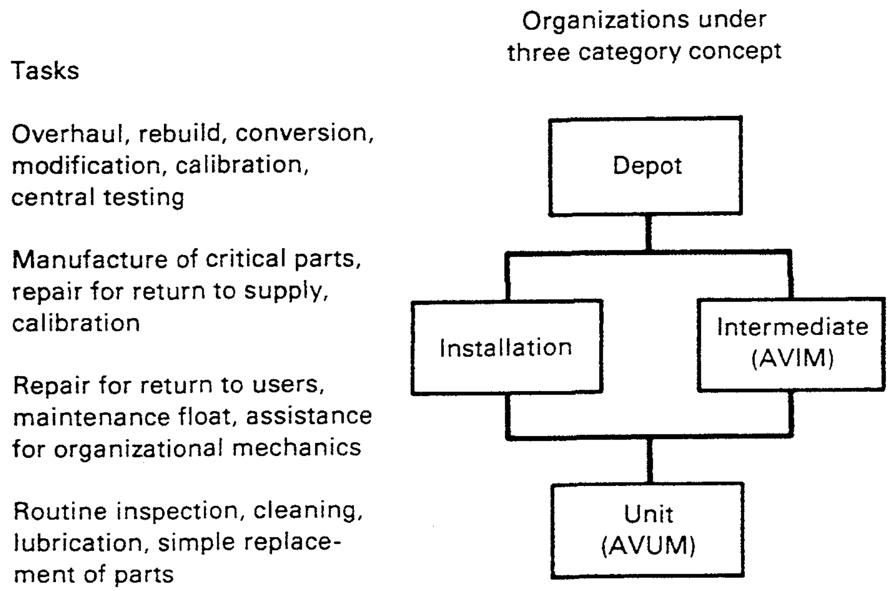

Fig. 1—The three-category concept for aviation maintenance

performance. Each shop had a different design, meant to serve the needs of the specific military units associated with the installation, but all were based on a single prototype. Finally, the military in-the-field shops all use military personnel. In CONUS, FORSCOM supervised their staffing levels, budgets, and performance; the U.S. Training and Doctrine Command (TRADOC) provided their design. All units were identical in design but could vary locally in availability of specific equipment and skills.

When we speak of Army maintenance, we can speak of any one of these shops or of all of them collectively. To understand resource allocation in Army aviation maintenance, we must understand resource decisions that occur within, between, and above each of these types of shops. The most difficult question about resource allocation in aviation maintenance is how the Army's form of organization affects it. Finding an answer to that question, of course, is the goal of this study.[4]

[4]Appendix B offers a more detailed overview of the Army's aviation maintenance structure. Appendix C reviews the information activities with which the Army tied this structure together in the late 1970s.

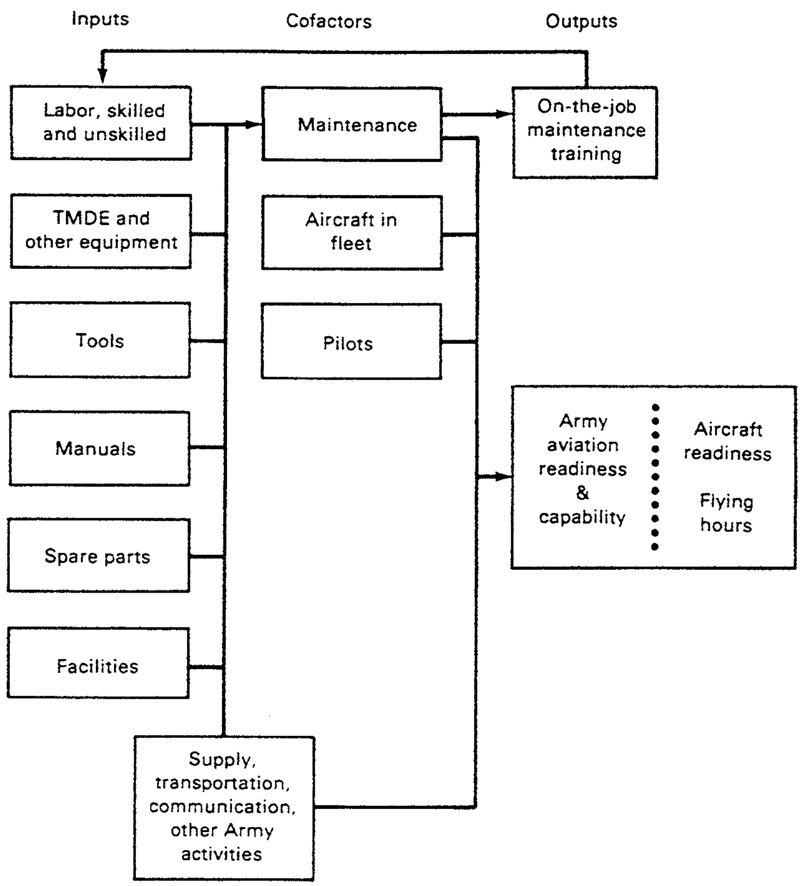

Fig. 2—A production framework

From a maintenance standpoint, it is useful to distinguish training and nontraining flying hours. In particular, for two reasons formal pilot training was likely to generate a greater maintenance workload than flying without a formal training component. First, by definition, much formal training was aimed at less experienced pilots. We should expect them to make errors that stress their helicopters.[7] Second,

[7]It is also possible that the kinds of failures they induce do not represent the failures we would expect in a combat environment. This is more likely to be important in a short conflict using only skilled pilots than in a longer one in which new pilots must be trained in combat. The argument could also be made, of course, that trainees fly heli-

formal training flights were likely to involve maneuvers that placed greater stress on the aircraft than routine flights. An example is nap-of-the-earth (NOE) flight, which required continuous change of direction and speed. NOE flight was an important component of formal training.

Flight simulators had a large effect on the relationship between flying hours and maintenance.[8] For many individual maneuvers, the simulator provided a close substitute for actual flight; the Army allowed aviators to substitute three simulator hours for two hours of actual flight in their annual flight requirements. In some cases, the simulator was even better than real flight. For example, aviators could attempt hazardous maneuvers at low cost. This was particularly helpful for inexperienced pilots. But nontraining missions and on-the-job maintenance training could not be produced jointly with simulator flight.

On-the-job training for crew chiefs and mechanics was a key helicopter service, but the Army apparently maintained no formal on-the-job training or apprenticeship program in military, installation, or depot shops. Therefore, we should concentrate on informal training.

From a maintenance point of view, two different types of informal training occurred. The first was for new mechanics with only their introductory formal training completed. This was most important in military shops, which had to absorb new mechanics with only rudimentary skills. That is, because the Army developed its own mid-level and senior noncommissioned officers (NCOs), it had a large junior enlisted force, which had to be trained and groomed to produce future NCOs. Civilian installation and depot shops had the option of going to the open market for skilled mechanics and supervisors, making this less of a concern to them. In fact, there is evidence that the military did much of the preliminary training—formal and on-the-job—for these civilian shops.[9] Within military shops, a good on-the-job training program for new personnel required close supervision by senior, knowledgeable personnel. Military shops could supplement

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copters "by the book" while experienced pilots are often tempted to fly them to the limits of their design capabilities and beyond. Such behavior can lead to larger maintenance workloads where experienced pilots are flying. The important point is that maintenance demand depends on the types of flying hours generated. Inexperienced pilots are also less able to pinpoint failures that arise during flight. Failures that go unnoticed will probably lead to more serious damage than experienced pilots would allow. Failures that are noticed but not diagnosed place a heavier diagnostic load on line and shop mechanics.

[8]The Army had simulators for the Iroquois (UH-1) on many installations and planned to install simulators for the new Blackhawk and AAH.

[9]Shishko, Paulson, and Perry (1977) found that many civilian mechanics on Air Force bases are veterans who received their training in the Air Force.

their own senior NCOs with assistance from field maintenance technicians (FMTs) and members of the MAIT team.[10] FMTs were typically better on problems specific to aircraft; MAITs were oriented more toward general maintenance problems.

The second type of on-the-job training was analogous to pilot training obtained in routine flight: Mechanics built their skills by practicing their trade. The practice of maintenance produces not only the direct, observable output of the maintenance manhours but also an increment to the skills of the mechanics employed. As modified work orders (MWOs) altered helicopters, as new diagnostic equipment (TMDE) or maintenance techniques were introduced, and as new administrative routines evolved, this experience had to be supplemented by quick refresher and reorientation courses to prevent depreciation of the accumulating skills. Continuing practice in the diagnosis and repair of simulated combat damage, not typically encountered in peacetime, was also desirable. But these more direct forms of training played a much smaller part in the training of skilled than of less skilled mechanics. Less supervision was required and less time needed to be devoted to activities that did jointly produce current maintenance.

The outputs of maintenance, then, can involve many subtly defined and differentiated products. A similar statement could be made about any of the inputs to maintenance above. But although these factors suggest that Army aviation is a complex activity, they do not detract from the simple fact that it is a production activity. It uses various inputs to *produce* various outputs. It is therefore susceptible to analysis with many of the economic concepts that have been developed to understand production activities.

PEACETIME SUBSTITUTION AMONG MAINTENANCE INPUTS

When the Army developed a new aircraft or any other major item, it also developed an extensive set of maintenance concepts that determined its requirements for various types of support equipment and skills. These typically dictated how the item was supposed to be maintained once it entered the Army inventory.[11] But the explicit set of

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[10]Field maintenance technicians were experienced civilians attached to the Logistics Assistance Office (LAO) on a post. A Maintenance Assistance and Instruction Team (MAIT), a team of military maintenance specialists, was designed to aid military maintenance units. Appendix C discusses these in more detail

[11]For details, see Appendix D.

skills and equipment prescribed was not the only set the Army might use to maintain the new aircraft. In fact, with very few exceptions, a given level of any service can be provided with many levels of different inputs. All that is required is that an increase in any one input, say skilled mechanics, *alone* increase some output. Then some other input, say inventories, can be reduced just enough to bring that output back to its original level. This two step process substitutes mechanics for inventories. Such substitution is possible in almost all service activities. In aviation maintenance, four broad kinds of substitutions are possible: within a shop, between shops, between maintenance and nonmaintenance shops, and between the Army and other producers.

First, within any part of the helicopter maintenance system, say intermediate maintenance, the Army can substitute among inputs. For example, more or better manuals, tools, or equipment allow mechanics to work faster, reducing the need for mechanics. More or better test equipment reduces the need for spares broken during or simply discarded following a diagnosis in which parts are replaced more or less arbitrarily until an aircraft works again.

Second, suppose the production process for a given maintenance task is different in one component of the maintenance system from that in another. Fixed shops, for example, use more test equipment and supporting equipment than field shops. Shifting that task from one component to the other changes the production configuration of inputs associated with the task and allows substitution among inputs. Theoretically, MAC charts assigned tasks to one component or another—say organizational rather than direct support maintenance. But, as noted above, they need not specify the only way to assign tasks to maintenance shops. Inventories allowed at various levels might similarly be revised over time.

A third form of substitution involves services the Army provides to helicopter maintenance organizations. One example is transportation of evacuated components from operating units to higher echelon repair shops. Another is the communication services required to track such evacuated components. By using more transportation or communication services, the Army might be able to reduce the inventories needed to maintain a given level of readiness or flying hours. Further, such services as transportation and communications are in turn produced by capital and labor inputs, and decisions to substitute among these "primary" inputs in general cannot ignore capital and labor inputs to helicopter maintenance through services outside the maintenance system.

The final basic form of substitution is a logical extension of that presented by transportation and communication services within the

Army. It involves services the Army purchases from other military services, government agencies, or the private sector. That is, by contracting out to get services in support of maintenance, the Army can effectively change the mix of resources it commits to producing given levels of maintenance outputs.[12]

Given the many different ways to produce a *certain* set of maintenance outputs, how does the Army choose among the options available? In essence, how does the Army make decisions about resource allocation? The answer is simple if it expects deterrence to be successful enough to avoid war. It should then attempt to produce this *given* set of outputs with the minimum expenditure of dollars.[13]

This simple solution does not address two serious problems for the Army resource allocator. First of all, he typically is not asked to produce certain outputs at minimal cost. More realistically, he is asked to provide certain maintenance services within specific resource constraints on manpower, materiel, and so on. What does he do then? If it is possible at all to produce the services within these constraints, the allocator probably has alternative ways to do so. We want him to minimize the monetary value of resources he commits to producing the required services. This will leave him with additional resources that might be used to increase further maintenance services or to produce other services within the allocator's purview, or that might be returned to the Comptroller to lower the resource constraints on activities beyond this allocator's purview. Which alternative to choose for these additional resources is a serious problem. On the one hand, we need to know how much each alternative use is worth, forcing us to place a monetary value on combat services generally not traded in markets if they are among the optional uses for the freed resources. On the other hand, not all of these options may be open to us; in particular, it may be impossible to induce the allocator to optimize his use of resources to produce maintenance if he must relinquish all resources not used. A critical part of minimizing the costs of maintenance is identifying procedures to induce those responsible for using resources to care about costs. In this report, we will not attempt to value combat services. We will give considerable attention to the

[12]For an example of how different private contractor operations look in terms of labor mix, see Paulson, Perry, and Shishko (1977).

[13]This is what Hitch and McKean would probably call a "proximate criterion" (1965, p. 160). It assumes that the prices the Army pays for inputs reflect appropriate social values of those inputs. For the most part, prices reflect appropriate social values if they are determined in a free market. Prices determined in administrative ways—for example, the wages paid to draftees, or the cost-accounting-based prices of services purchased from other government agencies—typically do not reflect appropriate social values.

problem of inducing managers to produce maintenance services with fewer resources.[14]

A second problem for the resource allocator is that the Army cannot assume it will be able to avoid active combat. Resource allocation for peacetime maintenance activities must be consistent with the Army's maintenance needs in wartime. Planning for wartime affects both the required levels of maintenance in peacetime and the prices of inputs at which the Army would want its managers to value resource decisions. The first point is obvious; the second may not be. Inventories and equipment stocks, skills, and methods of doing things developed and maintained in peacetime will be carried over to wartime, particularly in the early stages of a war. If the Army expects the *relative* scarcities of inputs to change from wartime to peacetime, it may want managers to prepare for such a change by simulating wartime scarcities in peacetime. This would mean that the Army would want to use input prices in peacetime that differed from those in the civilian economy. That does *not* mean that input prices are irrelevant under these circumstances. To the contrary, consistency of input prices across activities within the Army is critical to appropriate resource use in peacetime or wartime, and changing relative input prices during peacetime are likely to suggest similar changes in relative prices in wartime. We will give little attention to the actual choices of maintenance outputs "required" in peacetime or the way in which such choices are made. We will give a great deal of attention to the role of prices in peacetime and to the concern that changes in wartime could affect what prices the Army should use in peacetime.[15]

Given all these problems and considerations, the ultimate implementation problem remains. How can an organization as diverse and complex as the Army consider all the costs associated with the various substitutions suggested above? In the end, the ability of the Army—or DOD—to manage these substitution opportunities depends heavily on how "thousands of managers, who collectively make tens of thousands of daily decisions on consumption of resources, concern themselves with the outputs and benefits derived from each decision made" (Richardson, quoted in McClary, 1974, p. 2).

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[14]Withers (1962) provides an excellent discussion of the general incentive system used in military aircraft maintenance and its implications for considering resource inputs, the costs of these resources, and the services such a maintenance organization provides as an end product. In particular, it gives numerous concrete examples.

[15]For an extended discussion of conceptual issues associated with cost estimation and institutional design, issues of importance in this report, see Hitch and McKean, 1965, esp. Chaps. 9 and 12. This book is particularly useful because it addresses these issues in the context of resource allocation in DOD.

PERSPECTIVES ON INPUT COSTS AND SUBSTITUTION

Resource allocation to respond to changes in relative input costs can be organized from long, mid, and short-term perspectives. In the long term, the Army reacts to changing input prices by redesigning aircraft to permit substitution away from increasingly costly maintenance inputs toward other inputs. In the past, it has taken ten to fifteen years to design and introduce a new weapon system. As noted in the Introduction, the Army is pursuing this approach today. We do not discuss this perspective. In the mid-term, the Army rearranges the way it designs maintenance shops to maintain the aircraft it has in its inventory. This involves rewriting basic requirements documents for maintenance activities and acquiring the skills, equipment, and inventories called for in those new documents. In theory, this occurs in a three year cycle. Section IV examines these activities. In the short term, the Army accepts its requirements documents as given and provides maintenance with the resources available under these documents and the budget and other short-term supply constraints the Army faces. Today, this typically involves managing shortages of personnel, equipment, and inventories so as to maximize the maintenance services available from limited resources. Section IV examines these concerns.

III. RESOURCE ALLOCATION IN THE MID-TERM: ORGANIZATIONAL PLANNING

The Army viewed mid-term resource allocation in terms of requirements and authorizations for various assets in the late 1970s. Given a mission, an organization had a certain *requirement* for a detailed list of labor skills, equipment, inventories, and so on. Given these requirements, the organization was given *authorizations* to acquire some fraction of these assets. The authorized lists of assets were the basic planning documents for resource allocation in the Army. This section examines issues associated with writing these documents for organizations in Army aviation maintenance. These documents were based both on doctrine and on historical experience. The relationship between these two factors affected the process by which the Army could revise requirements and authorizations in response to changing input prices. This section discusses this relationship and the relevant information systems.[1]

DOCTRINE AND DATA: THE BASIS FOR REQUIREMENTS

The Army faced a basic dilemma in the late 1970s. Its organizations had to be designed to fight wars. Its doctrine emphasized the wartime mission, particularly for its military organizations. However, it spent most of its time and accumulated most of its experience in peacetime. Most of the formal information systems gathered peacetime data for the design of organizations. How could the Army use peacetime data to plan for wartime organization?

That question was an extraordinarily difficult one for the Army. It is easier to answer with regard to shops manned by civilians. Peacetime data dominated decisions on resource allocation in depots and installations. Resource demands in both depots and installation activities were driven heavily by historical and expected peacetime workloads. As a result, the staffing guides for depots and installations relied on methods and standards (M&S) derived from peacetime

[1]Appendix C describes information systems relevant to Army aviation maintenance. Appendix D describes the processes used to write requirements and authorizations for military units.

experience. Similarly, local appraisal teams based manning decisions very closely on current—peacetime—needs.[2]

The question was more difficult for military organizations. Here doctrine explicitly defined the combat mission of each organization and thereby dictated that combat needed to play an important role in resource allocation. In practice, the Army reached an uneasy compromise. Peacetime data were used extensively here, but their use was often tempered by a concern for the doctrine of organization for combat. The compromise was rarely very satisfying. For example, the Army based its levels of spare parts and components inventories solely on peacetime historical data in the late 1970s. In spite of the contribution these rules made to peacetime management, studies at that time found little or no correlation between the inventories dictated by these rules and those needed in high-intensity combat.[3] The Improved Wartime Repair Units Consumption Guides (WARPAC) and Sustainability Predictions for Army Spare Component Requirements for Combat (SPARC) programs began to make adjustments in war kits to remedy this. Despite this heavy reliance on peacetime data, however, Army officials *universally* stressed the primacy of managing resources to prepare for circumstances in the next war, even when they could not characterize anything about that war.

When the Army sought data on actual peacetime operations, it would generally rely on one of two major sources of empirical data in the Army, the Army Maintenance Management System (TAMMS) and formal audits and inspections.

TAMMS and SAMS

TAMMS was the primary data source for actual maintenance experience in the Army in the late 1970s. Among other things, TAMMS supported manpower requirements determination with data on annual maintenance manhours, requirements determination for inventories of spare parts, and baseline calculations of reliability,

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[2]Technically, all installations were organized to conform with DAPAM 570-551, *Staffing Guide for Garrisons*. Depots conformed with DAPAM 570-566, *Staffing Guide for Depot Maintenance Installations*. These documents listed the offices to be included in an installation or depot and the skills to be included in them. They grew out of date over time, however, and actual personnel authorizations, based on requirements in the Table of Distribution and Allowances (TDA), were quite often determined by "local appraisal." Surveyors (members of the Manpower Survey Team, discussed in Appendix C) from HQ FORSCOM for installations and HQ DARCOM for depots considered the commander's request for authorizations and, on the basis of their best judgment, decided whether the request was justified.

[3]See, for example, Dailey (1976), Palmer (1976). For a discussion of serious problems that persist in manpower planning for wartime, see Shishko and Paulson (1980).

availability, and maintainability in the development of new aircraft. Through these uses and others, TAMMS affected the requirements process in Army aviation maintenance at their most fundamental level. Its importance to resource allocation at that time cannot be stressed enough. It is also worth stressing that TSARCOM saw the role TAMMS played in scheduled maintenance as at least as important as any role it played in resource planning. TAMMS data effectively controlled when aircraft components would receive their scheduled maintenance. TSARCOM placed great importance on assuring appropriate maintenance of major components, suggesting that it kept a careful eye on any problems in TAMMS that might affect maintenance schedules. The data necessary for this role, however, were quite distinct from those typically used in resource planning.

TAMMS was based on a log book that maintained a historical record of the receipt, operation, condition, maintenance requirements, modification, and transfer of each individual aircraft. Selected data were extracted from these log books on a regular basis, reduced to machine-readable form, and forwarded to the Materiel Readiness Support Agency (MRSA). MRSA sent these directly to TSARCOM for compilation into regular reports to HQDA and the major commands on fleet status and various maintenance topics. These reports were used primarily above the installation and divisional level.[4]

TAMMS was widely recognized as an unsatisfactory data system, but the Army continued its use while looking for a successor. The Standard Army Maintenance System (SAMS) was the likely successor, but the date of its full implementation was still uncertain by 1978. Wholesale[5] segments of the SAMS were scheduled for introduction as early as FY 1980.[6] Unfortunately, the evidence available in the late 1970s suggested that it could suffer from many of the same problems TAMMS had then.[7] RAMLOG, an experimental alternative to self-reported maintenance data like TAMMS and SAMS, shed some light on these difficulties.[8]

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[4]For more detail, see Appendix C.

[5]"Wholesale" segments of Army logistics refer to depots, factories, and many national-level maintenance activities. "Retail" segments refer to logistics activities on an installation and in the field.

[6]In 1979, SAMS was being planned in three segments: HQDA, wholesale, and retail. DESCOM and MRSA will play central roles in the wholesale segment. The retail segment, being planned at LOGC, was to be introduced in FY 1982. HQDA, with primary responsibility for the full system, had not determined when its segment would be introduced. MRSA would act as its primary agent.

[7]A comparison of the promotional literature for TAMMS and SAMS is revealing in the similarity of the problems both were designed to solve. See Anderson and Roy (1971); Hammer (1975).

[8]RAMLOG, apparently an acronym for Reliability, Availability, Maintainability-Logistics, is an intensive sampling data system that AVRADCOM has used to collect

The most disturbing problem with TAMMS is probably the inconsistency of the data it provided. An Army Materiel Systems Analysis Agency report, for example, found that only 10 percent of a sample of TAMMS records were even internally consistent.[9] This is a problem that could be resolved by local editing of maintenance data.[10] Technically, this was one duty of the technical inspector charged with overseeing maintenance work. But one Army experiment showed that even where the reviewers were highly motivated and well trained, as many as 40 percent of maintenance records benefited from formal computer editing.[11] SAMS was expected to use some form of editing.

Another form of inconsistency is more difficult to identify in the data themselves; it is inconsistency in the application of TAMMS procedures across maintenance units and shops. A 1977 GAO report, for example, found that some aviation maintenance units reported no maintenance manhour data at all; others charged their full available time regardless of actual time spent.[12] In part, this reflected a misunderstanding of TAMMS procedures. Because of turnover, the local understanding of TAMMS had to be continually renewed by refresher courses. SAMS was to attempt to avoid this problem with simplified procedures that could be more uniformly applied, reducing the depreciation of knowledge among officers and NCOs associated with a transfer. Probably more important, inconsistency in application reflected a lack of concern about the TAMMS. TAMMS data were not generally used locally; as a result, local technical inspectors had little direct interest in their accuracy. A lack of interest at all levels was confirmed by a common practice in aviation maintenance. Unlike the rest of the Army, aviation maintenance continued to collect TAMMS data at the organizational level in the late 1970s. When local data reduction centers were loaded beyond capacity, these data were simply discarded, leading to a highly nonrandom sample of data on organizational maintenance.

To the extent that local units did worry about the quality of the TAMMS data they reported, they appeared to bias them in their own

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RAM data on existing helicopters and compare them with postulated RAM data for new models.

[9]Bell et al. (1973).

[10]Local editing simply involves a check of maintenance reports for accuracy. Internal consistency is one simple indicator of accuracy.

[11]RAMLOG used a batch editing process. A data system that replaced TAMMS in V Corps in Europe uses interactive editing, a more expensive but even more effective verification device. Technical inspectors often considered massaging TAMMS data an adequate or even more desirable substitute for editing the data. Batch editing cannot detect this; interactive editing is more likely to eliminate it.

[12]"Determining Requirements for Aircraft Maintenance Personnel Could Be Improved—Peacetime and Wartime," 20 May 1977.

favor. An Army Audit Agency report, for example, found that readiness levels and related maintenance performance measures were overstated.[13] Comparisons of RAMLOG data collected by observers with self-reported TAMMS data collected on the same events suggested that TAMMS data markedly overstated the manhours needed to perform maintenance. The TAMMS data reflected the methods-and-standards (M&S) standardized manhours expected to perform a task, but the RAMLOG data recorded hours a third to a half of this level. A TSARCOM official explained the discrepancy by saying that an observer's definition of time worked was narrower than a mechanic's. The mechanic's was likely to be more meaningful because it included nonproductive activities—for example, coffee breaks—essential to local morale, while the observer's did not. Differences by factors of two and three are difficult to explain on this basis alone.

Although most Army personnel understood that TAMMS had deficiencies, they consistently pointed out that eliminating such deficiencies would be costly. And ultimately, the choice of an information system is an economic one like any other: An additional dollar spent on data collection and control should yield at least a dollar in savings.[14] However, many Army officials with whom we spoke also implicitly questioned the advisability of using such data, particularly for resource allocation in combat activities. This will become more evident when we examine the process of writing requirements documents for combat organizations.

Audits and Inspections

Inspections and audits appear to have been similar in Army aviation maintenance. Both were typically reviews of an activity's conformance with regulations and official guidelines. We will not attempt to differentiate between them here except to note that inspections were sometimes unscheduled and appear to have been more important

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[13]"The Army Maintenance Management System," U.S. Army Audit Agency, Survey Report EC 76-223, 8 June 1976.

[14]"Most of the alternative systems with which we are familiar . . . fail the cost/benefit test and are marred by their own peculiar weaknesses," LTC James H. Weisflog, Chief, Organization and Force Development Division, U.S. Army Transportation School, personal communication, 29 March 1979. Mr. William H. Barthel, Deputy Director of Maintenance, TSARCOM, felt the same way: "We feel the TAMMS system by itself is not a problem but the effective implementation, control of data and less than satisfactory information being reported is a major problem and to a large extent is caused by resource limitations. This limitation would also affect the RAMLOG or similar systems. Alternative methods for the same reasons would, in fact, be very costly compared with the TAMMS/SAMS method." Personal communication, 2 March 1979.

to military units; audits were always scheduled and were more important to civilian shops.

Military aviation and aviation maintenance units were subject to a wide variety of inspections through the year; three of these appear to have been the most important. The Aviation Resource Management Survey (ARMS) was an external aircraft inspection lasting a week each year and covering everything from safety to logistics procedures. The Command Maintenance Evaluation Team (COMET) inspection was sponsored by the local Inspector General and gave relatively less attention to aviation than the ARMS inspection. The Early Deployment Readiness Evaluation (EDRE) was an unannounced test of an aviation unit's tactical capability in a staged field exercise.

Audits came from all levels. The General Accounting Office, Defense Audit Agency, and Army Audit Agency conducted ad hoc audits on specific topics that typically revolved around an installation's compliance with regulations and guidance from higher headquarters. The major commands used more regular audits to reconcile property books with equipment authorizations and monitor stocks of high-value items.

In general, audits could be used to collect three kinds of information: the degree of consistency between actual and self-reported inventories and performance, the extent to which actual performance was consistent with prescribed performance, and the nature of local adaptation and innovation. Inspections offered opportunities to collect similar information across units. Not all of these activities were consistent with one another. In the late 1970s, the Army's choice of activities to pursue in audits and inspections deemphasized collection of data on actual experience that might serve as a basis for resource planning. Most inspections in particular became special events not likely to represent routine operations in a unit. Both audits and inspections emphasized consistency with central dictates and gave little attention to detecting or recording local variation in practice. In fact, because units knew they would ultimately be audited in order to assure that they were following approved practice, evidence of local variations or adaptations were carefully kept out of official documents.

In general, inspections were not seriously demanding. Because they came so seldom, inspectors were probably reluctant to infer total performance from them. They felt that by giving subordinates a few breaks, they could be sure they did not catch a good unit on a bad day and give it a bad rating. As a result, however, inspections did not report actual performance to the extent that they could. This was aggravated by the fact that the most thorough inspections of aviation came from teams unable to follow up detected failures. The Aviation

Resources Management Survey (ARMS) team knew more about aviation than the COMET, for example, but could not return to determine that problems had been corrected.

A strong case can be made for having infrequent inspections and audits merely verify the congruence between self-reported and actual performance. This eliminates most of the random aspects of the inspection process—a randomness that encouraged inspectors to avoid punishing subordinates unless major problems were found. Audits typically did seek to verify such congruence. Such a verification exercise can more easily account for assets than for performance, but performance records can be designed to be verified by audit. Performance audits were not conducted during the late 1970s. More generally, the savings on performance improvements projected in justifications accompanying equipment and facilities requests did not have to be verified once these items were procured and put in place. The accounting practices that would have developed out of auditing performance on these items could have been used elsewhere as well.[15]

Army officials displayed a variety of feelings about using actual historical data. On the one hand, the "experience" factor played a major role in most decisions made in the Army, particularly at higher levels. On the other, these officials were reluctant to look systematically at the past and to measure the effects of past proposals. The "experience" factor Army officials so often referred to involves personal experience, not systematically audited experience. The result was that reforms, like the SAMS, were typically future-oriented and therefore could fail to address some of the simplest failings of past systems. More attention to the role of audits, not just as monitoring devices but also as planning devices, could correct part of this.

A primary difficulty with any audit oriented toward verification, of course, is that it confines behavior to a predetermined pattern; it inhibits innovation and local adaptation. The Army recognized this; its leniency in inspections reflected in part its reluctance to repress the initiative of local commanders. With important exceptions—for example, the Aircraft Component Intensive Management System (ACIMS) and Aviation Intensively Managed Items (AIMI) programs—the Army tolerated local variation. Officially, all regulations stood; unofficially, it was accepted that some would not be enforced.

Unfortunately, inspections based on this premise could not actively seek out the places where current regulations were thought unsatisfactory and use the actual local variations in these areas as a basis for

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[15]The Value Engineering and Quick Return on Investments Programs (QRIP) do provide for some forms of audit. But the methodology used is relatively primitive. DAPAM 37-4 (1976), pp. 57-8, 61-2. Cf. McClary (1974).

better regulations. Regulations could often be written with little empirical input because the Army knew that informal adjustments would allow adaptations of these regulations. The control one expects in formal regulations and their enforcement through audits and inspections does not exist when local adaption is tolerated. And the local variation cannot be exploited to establish control in the future.

TAMMS and inspections and audits, then, were the sources of information most likely to inform Army planners and managers above the operating level about the *current* status of resource use in Army aviation maintenance organizations.[16] They yielded data more likely to confirm expectations than to measure local adaptations to current circumstances. To the extent that local shops cared about the TAMMS data they provided, they tended to provide data that their monitors expected to see—based more on standards than on experience. Similarly, inspections and audits tended to emphasize conformance with standards and give little attention to the local variation typical of routine operations. In sum, the Army's principal sources of information on current practices provided few empirical insights that planners could use.

These explicit systems were augmented by extensive informal information networks. Business and social contacts among individuals enhance the flow of information in a large organization, particularly one like the Army in which so many different functional activities participate in single resource decisions. But individuals in informal networks rarely fully understand the sources of information they receive or the way it will be used once passed on. Each individual in an informal network is typically guided in his information function by simple administrative rules whose usefulness deteriorates over time as the sources and uses of data change. Their limited view of the information flow prevents them from detecting this. When they do, they tend to adapt by calling up notions of received doctrine or personal experience, both of which reaffirm the need for the information flow and its original purpose. For this reason, informal networks persist long after their usefulness has ended. Because they do not follow official organizational lines, they may persist through one organizational change after another, unconsciously subverting many of the reforms intended

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[16]A more objective and informative information system appears to have resided in the system of Logistics Assistance Offices (LAOs) run by DARCOM. Located at each installation, these offices continually monitored trends in maintenance. They appear to have given more emphasis to technical than to organizational or cost issues. The DSCLOG Aviation Logistics Office also monitored trends closely, giving primary attention to safety issues. The systems discussed in the text were directly concerned with the broad empirical monitoring likely to yield insights about resource allocation. For some more detail, see Appendix C.

by such changes. They encourage a conservative approach to resource allocation both by perpetuating the use of obsolete information and by making it costly to end the use of such information.

MILITARY REQUIREMENTS AND AUTHORIZATIONS

Tables of Organization and Equipment (TOEs) defined, among other things, a military unit's requirements for manpower skills and equipment. Modification Tables of Organization and Equipment (MTOEs) defined their authorizations. Both of these depended in turn on the Manpower Authorization Criteria (MACRIT), documents that linked maintenance skills with aircraft. A complex process, involving all the Army's major commands, underlay their writing. Appendix D describes that process. Two major problems emerge from this resource allocation process.

First, the process was slow and discouraged change. Deadlines prescribed in regulations for the revision of the MACRIT and TOEs were routinely overridden. Delays in revision of the MACRIT were longer than those for TOEs but delays for both were serious. FORSCOM aggravated this problem by attempting to make all its MTOEs uniform; this automatically introduced delays similar to those in the TOE process. Any individual commander who sought to change his own requirements faced the probable cost and delay associated with changing *all* FORSCOM MTOEs for the TOE that formed the basis for his MTOE. This was bound to discourage commanders from submitting change requests to benefit their own units.[17]

Second, and more serious, all this cost and delay did not effectively bring all the information available to bear on the TOE/MTOE process. In spite of constant cross-checking and consultation within and between major commands, many decisions in the process continued to be made on an "other things being equal" premise: each major command made decisions on the basis of assumptions about the other major commands' activities that the process did not validate.

A very simple one is the validity of the MACRIT. The MACRIT was only as good as the TAMMS data on which it was based. Yet many TSARCOM officials believed that the TAMMS yielded only pseudodata on direct production annual maintenance manhours (DPAMMH) when all "adjustments" were completed. As described in the previous section, the TAMMS data were often the product of a local effort to

[17]This problem did not arise in the revision of FORSCOM's requirements for civilian maintenance shops.

record an expected result. And what were these expectations based on? In part, they were based on methods and standards developed by a prime contractor. Such standards could encourage excessive maintenance in order to assure performance.[18] These problems relate only to the direct productive time component of the MACRIT; similar concerns could be raised about the indirect productive time component. By the late 1970s, the Army had recognized many of the MACRIT's problems.[19] Various efforts were under way to correct the deficiencies. However, until these studies are completed and coordinated, the MACRIT will continue to play a central role in requirements formulation.[20]

Another example is the matching of skills, equipment, and capability in the resource planning process. The most obvious misunderstanding was that between FORSCOM and TRADOC over who would provide maintenance training. It was exemplified by the following assumption in a TRADOC MACRIT study:

> No allowance has been made in this MACRIT for the reduction in individual effectiveness of replacement repairers caused by the TRADOC policy of shifting technical training responsibility from the institution to the unit. In the past, the newly assigned repairer received complete MOS qualifying training prior to arrival in the unit and with three or four months of on-the-job experience was generally considered fully productive. The new philosophy requires formal on-job-training sessions in the unit during which the recent arrival is exposed to many essential repair tasks for the first time, acquires and sharpens his/her mechanical technique and repair skills, is given written/practical application examinations to see that he/she meets the standards and is then accorded the status of "journeyman" repairer after some unpredictable time in the unit. Not only

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[18]RCMS studies began to discover this problem throughout the Army in the late 1970s.

[19]Cf. Alvarez and Randall (1976). Shishko and Paulson (1980), which draws on circumstances within U.S. aviation units stationed in Europe, suggests additional problems. First, although the MACRIT attempts to consider wartime circumstances, it spreads workload evenly over time. This neglects the surge of flying hours and hence maintenance required early in a war as well as the loss of aircraft and hence reduced maintenance load as the war progresses. It also neglects battle damage and assumes all zones required for maintenance will be available during a war. Further, annual productive manhours have not been revised since the late 1960s and have not been validated in terms of current thinking on alternative wartime scenarios for maintenance requirements.

[20]In addition to being used as a management tool, the MACRIT was also a primary input into planning models used at CAA, the agency responsible for long-term operational planning and tactical and strategic analysis in the Army. It would be unfair to suggest that the Army does not recognize the problems in the MACRIT. The Total Logistics Readiness/Sustainability (TLRS) study sponsored by HQDA DCSLOG represents one attempt to deal with it in its role in operational planning. But no attempts were made in the late 1970s to address the larger problem of general coordination that underlies basic problems in the MACRIT.

> is the trainee less than fully effective during this phase, qualified repairers and supervisors are torn away from mission productive effort to accomplish the never-ending training and testing.[21]

FORSCOM did not accept this responsibility. OJT programs received little command emphasis and were difficult to carry out in any case for lack of trained personnel. In particular, senior NCOs available in the late 1970s had not been trained to supervise training activities. New senior NCOs had not had enough hands-on experience to provide OJT even if they were trained to teach. FORSCOM's disinclination or inability to provide OJT suggested that future senior NCOs would probably be even less able to provide OJT.[22] The first major revision in the aviation maintenance MACRIT in 12 years, one that was likely to stand for another decade, ignored this decline in the skill of maintenance personnel.

The problem looks even more severe when we consider that most ground support equipment in a maintenance unit was not developed specifically for the Army. It was typically bought off the shelf from firms typically selling to the private, nondefense market. The manuals accompanying off-the-shelf equipment were written in technical language. The Army's SPA programs were designed for mechanics with a fifth grade reading level. To some extent, this problem stemmed from federal Small Business Administration (SBA) regulations, which required the Army (and other services) to acquire a portion of their assets from small businesses. Because major systems could not be bought from these manufacturers, SBA purchases disproportionately affected such smaller equipment as ground support equipment. The profusion of models procured under SBA regulations confused SPA-trained mechanics. Because they could not use the manuals written for this equipment, models different from those on which they were trained were inaccessible to them.

Additional difficulties arose from the way the Army's Quantitative, Qualitative Personnel Requirements Information (QQPRI) documents were typically written. The QQPRI writer, often a prime contractor,

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[21]MACRIT Revision for Aircraft Maintenance, p. 6.

[22]This was aggravated by reforms in the Army's training programs. Formal training in TRADOC had become more structured and less dependent on the student's absorption of principles. Tasks and ideas to be learned were structured into logical sequences of steps. "Cookbook" manuals, designed for mechanics with fifth grade reading skills, complemented this training approach. This Skill Performance Aids (SPA) technique yielded manuals that broke down routine maintenance tasks into simple steps that could be executed with the aid of a checklist. Although this approach allowed unskilled mechanics to execute routine maintenance tasks, it did not build the adaptive skills needed for operation outside the ideal classroom/cookbook environment. As a result, it did not build the skills in mechanics advancing to leadership roles providing the on-the-job training required to complement such formal training.

expected—and was told to expect—a certain standard for the maintenance shop in which his equipment would be maintained or used. The QQPRI writer markedly overestimated the capability of the shop.[23] To the extent that he wrote the manhour requirements, the prime contractor's overstatement of maintenance needs might tend to balance his understatement of manhours per task. Unfortunately, his statement of maintenance needs entered the SPA technical manuals, MAC charts, and regulations that govern maintenance, allowing the maintenance shop to provide maintenance within its constraints only by disregarding these documents. SPA training was poorly designed for allowing mechanics to determine what maintenance could be disregarded.

Although Army officials were aware of all these problems, they did not always see them as individual symptoms of a much deeper and more profound difficulty. Each of these problems—TRADOC's unwillingness to reflect FORSCOM's training problems in a new MACRIT, the inability of SPA-trained mechanics to use equipment purchased to meet SBA requirements, and the inconsistency between the maintenance shops imagined when maintenance documents are written and those that actually exist—resulted from a failure of one Army office to communicate effectively its *current, actual* status to another Army office.

Some Army officials suggested that whatever problems existed resulted from external forces that would not constrain Army operations in wartime. When war came, skilled mechanics would be available, SBA regulations would no longer apply, and maintenance would be executed properly. Hence, there was no pressing need to communicate about current, actual peacetime status. Aspects of this view underlie the TOE process' failure to allow adequate time for review by operating units likely to be affected.[24] They also were present in the remarkable narrowing of options available to FORSCOM at this point in the process, even if its units could respond. To the extent that experience was systematically consulted, through the MACRIT/TAMMS, it was through a version of experience filtered to support certain preconceived notions about the world.

In fact, the two basic problems underlying the writing of military requirements and authorizations documents—delay and poor intra-Army communication—were related to the problem of collecting data on current experience. The Army's doctrinal view of the world often had more force than experience would, even if it were observed directly, because TOE development considered only wartime needs.

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[23]For example, see Alvarez and Randall (1976).

[24]See Appendix D.

One reason frequently given for TRADOC's lack of interest in feedback from FORSCOM units was that their points of view are inherently parochial and not suitable to the overview TRADOC could bring to bear through its development of concepts and doctrine. Wartime arguments and other rhetorical devices that abstract from actual, current conditions probably had as much force as they did because the data available on actual experience were so poor. In fact, the Army's sincere belief in the primacy of its wartime mission may have made it reluctant to consider peacetime information and coordination systems whose successful operation might obscure the primacy of the wartime mission.

FORMAL COST MODELS IN ARMY AVIATION

Despite the Army's difficulties in bringing current data to bear on resource allocation issues in its military organizations, it showed an increasing interest in the late 1970s in costing aviation organizations that met certain doctrinal specifications.[25] This subsection briefly reviews the Army's efforts in costing Army aviation maintenance units.

Such efforts had to rely heavily on costing models developed to support new weapon system acquisition. These models generally did not allow the type of analysis required to detect and exploit desirable input substitutions. DAPAM 11-4 offers a good example. It presented an accounting system for operating and support costs, costs we would associate with maintenance. This system was fairly well designed for considering life cycle costs of a new weapon system program, *given* the support configuration. But it could not be used to provide reliable per-aircraft (UE) costs. And it could not be used to weigh alternative support configurations within a maintenance shop.[26]

The treatment of several specific cost topics in AVSCOM and AVRADCOM costing documents share similar problems.

The user's guide to the AVSCOM Maintenance Operating and Support Model (AMOS) confused the need for a discount rate with the

[25]For example, Hogan (n.d.) analyzed the cost of operating specific helicopter types in units with different TOEs.

[26]Conceivably, it could be used for these things, but only in the most awkward way. A production function could be manipulated to provide configurations that could then be costed within the DAPAM 11-3 framework, but then that framework becomes superfluous. Using this document or its companion pamphlets for "designing system support configurations or to determine maintenance concepts" is "of course" inappropriate, according to Wayne M. Allen, Director of Cost Analysis, within the Comptroller of the Army. Personal communication, 19 April 1979.

need to correct for inflation.[27] In part, this was a result of poor guidance on discounting in AR 11-18 and DAPAM 11-4.[28] AVRADCOM, for example, treated the discount rate more as a DOD-imposed tax or regulation than as a price reflecting the relative value of equipment and other assets on the one hand and labor and leased services on the other. In particular, adjustment for risk was considered of second-order importance in spite of the central role of risk in innovation and the routine use of higher discount rates for innovations in business.[29] Similarly, no thought was given to the possibility that the discount rate might appropriately differ across activities within Army aviation maintenance or even DOD as a whole to reflect differing scarcities of funds. Such issues were treated as if they were reflected in OMB's choice of a 10 percent real rate and were now beyond question. In any case, although an understanding of the discount rate as a cost and hence a measure of relative scarcity was not necessarily important to a calculation of total program costs that would be used to predict budgetary requirements, it was imperative to the consideration of efficient input substitutions.

Second, AMOS and other cost models used at AVRADCOM made extensive use of crude average cost estimates. An example is a parametric equation for the estimation of depot labor costs (Vandrey, 1977, p. 13)

$$\mathrm{ADML} = (\mathrm{AOR})(\mathrm{DMLR})(\mathrm{RF})(1561.8645 + .34617\mathrm{EW})$$

where ADML = annual depot maintenance labor costs, AOR = annual overhaul rate, DMLR = depot maintenance hourly labor rate, RF = a reliability factor, EW = empty weight, and the last term is a least squares estimate of maintenance manhours per overhaul.[30] This equation assumes the structure of depot maintenance within it. That is, none of the arguments on the right side of the formula is

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[27] "It was considered possible that there would occasionally be a requirement to calculate and display escalated O&S costs. . . . In such cases it was . . . deemed desirable that a discount procedure be incorporated, in order to display O&S costs in dollars discounted to present value." Luker, Stanard, and Thomas (1977), p. 5.

[28] The problem of using an appropriate discount rate is not restricted to the Army. It exists throughout DOD and presumably throughout the federal government.

[29] In competitive markets, riskier investments typically earn a higher expected rate of return than less risky investments. This observation has led to a school of thought that supports the case of a higher cost of capital for riskier projects in the public sector. Economic price theory does not always support this school of thought, though it makes clear that projects with different levels of risk should be treated differently in cost-benefit analysis. Cost analysts in the Army give such concerns little consideration. For a good discussion of these issues, see Hirshleifer (1966), Shishko (1976).

[30] Note that we get no guidance about the predictive power of this equation, or its relevant range of application. We get no indication either of how sensitive the cost model is to possible inaccuracies or perturbations in the parameters of this model.

responsive to changes in the mix of inputs used to produce maintenance. Although such an equation *might* be useful in forecasting total costs, it has little to recommend it in force design.[31]

The emphasis was on cost analysis as a budgeting tool rather than as a method for studying tradeoffs. Although these models were all designed for the specific purpose of costing new weapon systems, their approach was consistent with DOD's view of Planning, Programming, and Budgeting (PPB):

> Military plans are prepared on various force levels encompassing varying degrees of risk with limited regard to resource limitations. Budgeting, on the other hand, is concerned with the detailed application of resources in the execution of assigned missions. This involves not only the expression of plans in dollar estimates, but also the required financing, accounting, distribution of resources to major commands, analysis of resources utilization, and justification of financial estimates to higher authority in the form of a budget. The initial role of programming is to translate plans and objectives into specific scheduled actions and identifying in relatively precise terms the required resources. The program serves as a basis for determination of the budget estimate. In this way programming serves as a bridge between planning and budgeting.[32]

Although cost-effectiveness studies were a basic goal of this system, the primary emphasis was on costing a given force structure. In a sense, this function was consistent with the zero-based budgeting concept of building up an agency's budgetary needs from those of individual activities. But it took the emphasis off comparison of alternative activities and activity levels and put it on the costing of standing activities. This was a difficult task in itself but, as we have seen, not sufficient for resource decisions.

In sum, cost models available to the Army in the late 1970s were designed more to predict budgeting needs than to consider alternative organizational structures. Before the Army could consider the cost implications of organizational alternatives, it would need cost models more amenable to *ex ante* decisionmaking than to *ex post* accounting or budgeting control.

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[31]Other approximations are also used. The worst examples are cost data taken from the *Army Force Planning Cost Handbook* (COA, June 1976), which the Army rated as only a fair source of information (AMSAA, *Visibility and Management of Support Costs: User Survey*, June 1977). Data from the Handbook or AFPCH were used extensively in Army force structure studies in and out of aviation. COA was developing accounting systems to reduce the Army's dependence on the AFPCH in the late 1970s. But even these, like the AFPCH, will generate average cost figures that are inappropriate to evaluations of resource choices. Cf. Morgan et al. (1974).

[32]DAPAM 700-1(1976), pp. 25-9 to 25-10.

SUMMARY

Our research suggests that the processes the Army used to design aviation maintenance organizations during the late 1970s could not properly consider changes in input prices. We cannot claim to have proved this point in the limited time available to us, but we can offer considerable evidence consistent with such a hypothesis.

First, the two principal formal information systems that could support resource allocation decisions for Army aviation maintenance yielded few insights that policymakers could use to design combat organizations. TAMMS data appear to have been adjusted once at the maintenance shop and again at TSARCOM to assure that the data more closely reflect expected outcomes. Inspections and audits, to the extent that they were able to monitor actual operating circumstances, emphasized compliance with preset standards. They explicitly did not seek data on creative local adaptation. Both information systems thus tended to report self-confirming data, unlikely to trace changes in relative input prices or reactions to them.

Second, informal information networks in the Army, as in any large organization, appeared so complex that no one person really understood them. Such networks tend to be self-perpetuating, moving and adjusting data in a way that maintains set perceptions of maintenance in place over time. Hence, such networks do not reveal the conservatism of more formal information systems; if anything, they affirm it.

Third, though all major commands had a formal role in writing requirements documents, the role of the user—for example, FORSCOM—was quite attenuated. The role of units most likely to have good knowledge of actual operating experience was even more attenuated. TRADOC, the command finally responsible for requirements documents, presented the views of such units as being parochial and inappropriate to the design of prototype combat organizations for the Army as a whole.

Fourth, within FORSCOM, local adaptation of organizational authorizations by units with current operating experience was further discouraged by a requirement that all changes in authorizations be made universal within FORSCOM. This might have provided interchangeability of units in combat, but it markedly reduced the local incentive to promote change.

Fifth, this general caution about using data on current experience explains, at least in part, the Army's difficulty in coordinating major commands to make resource decisions. Because each command did not derive its perception of the needs or capabilities of other commands from current experience, the major commands often made inconsis-

tent resource decisions. For example, TRADOC changed training doctrine without accounting for FORSCOM's perception of its role in on-the-job training or DARCOM's perception of limitations on its acquisitions of equipment. These inconsistent decisions created problems that Army officials often failed to see as resulting from a common procedural perspective in the Army. To the extent that major commands communicated through informal information systems, we could expect these inconsistencies and misperceptions to persist.

Sixth, the absence of accurate data on current experience at the highest levels of the Army suggests that very different perspectives on resource use would exist in different parts of the Army. Officials near the operating level should have good information on resource problems but a poor perspective on the connections between them. At the top of the Army, planners and other decisionmakers should be aware of general difficulties but, lacking good cross-sectional data, be unable to perceive coherent trends or associations between problems. Planners responded to evidence of problems by using personal memories from their experience in operations to structure solutions and taking a future oriented perspective that could be judged by prevailing perceptions of doctrine but not evaluated empirically. In a period of rapid change, such an approach would not be particularly responsive to the changes relevant at the operating level, particularly changes in relative input prices.

All of these symptoms seem to come back to a symbiosis between doctrine and the cost of collecting current data. On the one hand, the doctrine of combat orientation questioned the utility of current data. On the other hand, the cost of getting relevant and accurate data made doctrine more attractive as a vehicle for resource planning. The role of doctrine and the cost of information in planning civilian maintenance shops were both smaller; the resource problems also appear to have been smaller. The ultimate reconciliation of doctrine and data in resource decisionmaking will depend on understanding better how to use peacetime experience to plan for war.

IV. RESOURCE ALLOCATION IN THE SHORT TERM: OPERATIONS

Maintenance operations occurred within a constrained environment defined in large part by the organizational forms that Army planners had developed in the late 1970s. This was particularly true of military maintenance operations but applied to civilian operations as well. To a large degree, Army doctrine visualized the military commander more as an administrator of prescribed practice than as a manager of costly resources. In theory, planners played a greater role in resource use than operators. Doctrine gave supervisors of civilian operations more responsibility for decisions on resource use, but still reserved a considerable proportion of authority for planners.

In fact, the actual practice of Army aviation maintenance called for managers, both military and civilian, with considerable skills in allocating available resources to their best uses. Because requirements and authorizations documents, particularly for military organizations, did not respond rapidly to changes in the availability of resources, maintenance supervisors had to continually improvise and innovate. As a result, despite the intentions of doctrine, operators played a major role in resource allocation within Army aviation maintenance.

GOALS OF MAINTENANCE SUPERVISORS

The goals of operations in aviation maintenance presumably reflected the incentives its supervisors faced. This subsection first reviews the principal operations goals created by the Army's predominant "promotion incentive." Reordering the use of inputs to reduce cost in the face of changing relative input prices was not among these goals. If cost reduction enhances a manager's ability to pursue these goals, it can occur as a by-product. This does not appear to be compelling. Selected "material incentives" promoted some cost reducing innovation. But, on the whole, incentives in Army aviation maintenance did not directly make cost reduction through resource reallocation a dominant goal.

Although Army aviation maintenance used a variety of forms of incentives to motivate supervisors, the predominant one was the pro-

motion incentive.[1] Those whose evaluations suggest that they had performed well were rewarded by promotion to increasingly prestigious, responsible, and presumably lucrative positions. The central importance of the promotion incentive suggests that its criteria should have affected the conduct of Army aviation maintenance.

The central precept of Army aviation maintenance was "readiness": Maintenance keeps combat units ready.[2] Hence, we should not be surprised that maintenance supervisors saw readiness as the central feature in their evaluations for promotion. Because of the differences among Army maintenance shops, however, the view of readiness differed slightly from one type of shop to another.

Readiness was most directly relevant to military supervisors. Without exception, the military personnel to whom we spoke saw the readiness of personnel and equipment for which they were responsible as the most important element considered in judging them. The second most important concern for promotion was the performance of a military supervisor's unit in annual standardized tests.

Supervisors of civilian installation shops also regarded readiness as their greatest concern. They reported directly to a military division or corps commander, who was himself judged by the readiness of his troops and equipment. Installation personnel saw backlog as an additional measure of performance. They regularly reported their level of backlog to HQ FORSCOM, which, if it observed an unusual backlog, would inquire about the cause. But FORSCOM took no other action. The installation shop was directly responsible to the division commander whose performance was measured by readiness.

Readiness was relevant to civilian depot supervisors, but they were so far from military units themselves that it was expressed indirectly. Depots sold their services to readiness commands.[3] These commands

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[1]Others used were moral incentives, which reinforced a supervisor's commitment to the Army and the social importance of its goals, and material incentives, which linked a specific reward to a supervisor's attainment of any specified set of goals (cf. Montias, 1976). Moral incentives pervaded the Army but are extremely difficult to measure or evaluate. The Army's (and federal government's) view of property rights within federal service severely limited the role of material incentives.

[2]"Readiness" was a technical term in Army aviation and was explicitly defined and monitored in two information systems. For details on these systems and the definition of readiness they used, see Appendix C.

[3]For example, TSARCOM paid for all the Army aircraft overhauls Corpus Christi Army depot performed on a per-unit basis. The transaction was not direct: "The U.S. Army Depot System Command issues authorizations to depots to expend industrial funds against funded orders. Program (OMA) funds are used to reimburse the industrial fund working capital." Michael C. Sandusky, Army Depot System Command, personal communication, 22 February 1979. Note that the depots also sold services to non-Army customers. Our discussion bears only on sales to the Army aviation community.

monitored the quality of services delivered, in terms of both quality of overhauls and length of turnaround time in overhaul. Depots also constituted significant local political constituencies, however, giving them leverage outside the maintenance system itself. In sum, their goals appeared to be somewhat more diffuse than those of installation and military shops.

Our research suggested that cost reduction per se did not appear to play a major role as a direct criterion for promotion in any of these maintenance shops. The efficiency report, on which promotion of military personnel depended, did not mention cost reduction. This does not prevent a supervisor from using cost reduction as a criterion for writing efficiency reports, but he would do so only if he himself had an incentive to pursue cost reduction. In fact, the Army carefully circumscribed the role of cost analysis in operations.[4] Cost analysis could be used to evaluate only "mission nonessential" activities.[5] We were unable to obtain a consistent definition of "nonessential," but an activity was more likely to be essential if it directly affected combat capability.[6] Further, as noted in Sec. III, the Army maintained no formal methodology for measuring or auditing cost savings even when they were considered important.

Even if cost reduction did not affect a supervisor's prospects for promotion directly, it could free up resources that he could apply elsewhere to enhance relevant measures of output such as readiness or backlog level. This is important if the supervisor has not yet achieved his required levels of output. Once these are achieved, however, the supervisor has an incentive to pursue efficiency further only if he can retain the cost savings for use elsewhere.[7] In general, Army doctrine

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[4]Army doctrine on cost analysis was defined in a number of documents. The most important were AR 11-18 on cost analysis, AR 11-28 on economic analysis, and AR 235-5 on commercial and industrial activities. Several DA pamphlets supported these, the most important being the 11-X series on costing Army materiel systems.

[5]The documents themselves did not state this. But individuals in several offices stated that this was their understanding of the Army's costing program. They believed it must have been a result of a "statute, regulation, or a directive of higher authority, which preclude[s] any choice or trade-off among alternatives, including alternative ways to accomplish a program or project" (AR 11-28, para. 1-3d(3)). Whether this regulation was the exact source or not, the important point is that people responsible for weighing alternatives limited their own attention to mission nonessential activities.

[6]A recent GAO Report supported this conclusion. It found that only six of 139 proposed construction projects in FY76 and seven of 54 proposed construction projects in FY77 were supported by economic analysis in the Army. Further, the projects supported were smaller than average. Economic analysis was often used more to sell a project than to choose it from among a group of alternatives. Similar problems existed in the other services. GAO (1977a). Cf. Sears (1974), p. 50; Edmunds (1974).

[7]Thomas McNaugher (personal communication) offers the following example. A maintenance shop may have reached its output requirements, but the division in which it lay had not. Under such circumstances, the division commander would have a clear incentive to include cost reduction in the maintenance commander's

called for the release of funds or resources—including staffing—freed up by cost reduction. This removed any incentive to reduce costs, affecting civilian shops, that had some control over their resources, more than military shops. In fact, because staff reductions may have reduced the opportunities for promotion, this may actively have worked against cost reduction.

Because depots sold their services and operated primarily on the basis of revenues received from sales, costs could have been an important factor in their performance. But the price a depot charged need not have been tied to its cost,[8] and in any event only limited competition existed among depots. In fact, the Army had increased the specialization of depots in the mid 1970s and in the process reduced the amount of competition allowed. For airframes, none existed; any maintenance task was performed either at Corpus Christi or at New Cumberland, but not at both. Some competition may have been possible in avionics between Sacramento and Tobyhanna, but the amount is unclear. The readiness commands could contract out portions of their maintenance workload. DOD required that at least 30 percent of all depot maintenance be performed in the private sector.[9] Congressional politics played an important role in determining the workload at any depot, leaving only marginal adjustments in specific tasks susceptible to cost competition. High costs were often excused as a result of excess capacity required for wartime.[10] In the end, costs played a more nearly central role in judging depot maintenance than in judging other Army maintenance, but Congressional politics diluted much of the effect that it might

efficiency report so that the division could use any funds the maintenance commander was able to release. Careful attention to organizational relationships is obviously quite important here.

[8]Appendix E discusses this in detail. It is worth noting here that depots refused to break out the individual components of cost associated with a job when they quoted a price to a customer. This not only raised questions about the relationship of cost and price, it also made it more difficult for customers to conduct adequate cost comparisons.

[9]DODD 4151.1 (June 1970) required a readiness command to contract for at least 30 percent of its depot maintenance and to take the rest from Army depots. This did not have to apply to every weapon system. DOD applied the split to broad categories of equipment within each service. In the Army, aircraft were treated as a separate category. For example, contractors provided all overhauls for the new Blackhawk helicopter and the C-12 airplane. Overall, no more than 70 percent of TSARCOM's budget could remain in-house.

[10]The Army's "rationalization" program, still in progress in the late 1970s, held the potential for rewarding low-cost depots by giving them "primary" status and giving more costly depots the lower workloads—hence lesser ability to maintain jobs. But the primary criterion for distinguishing between categories was effectiveness or essentiality. Whether locations near ports, airfields, and Army units or simple politics played a bigger role in defining these is unclear.

have on cost consciousness. In particular, cost performance did not appear to affect the survival of individual depots.[11]

Material incentives supplemented promotion incentives in installation shops and depots through the Suggested Improvement Program. The Civilian Personnel Office in HQDA supervised this program. It created incentives by paying bonuses for specific innovations. Similar programs existed for military maintenance units in the field. Where bonuses were offered, the mechanics pursued them. Two problems existed. First, innovations were rewarded only if they were formally presented so that an unbiased observer—someone unfamiliar with the personnel in the shop—could consider the innovation and determine its worth. The chance that a supervisor in a local shop could reward his mechanics dishonestly was a real one, but this way of avoiding it seriously discouraged innovation. By leaving the decision about a reward to someone unfamiliar with the shop, it biased innovation away from exploitation of local targets of opportunity.[12] More important, it asked too much of the mechanics. An innovator might be able to explain his idea to the judge directly, but he often had difficulty presenting it formally. Such a means of judging innovation did not take advantage of the mechanic's comparative advantage.

The second problem with these bonus programs was that the reward associated with any innovation was highly uncertain. It was generally left to the discretion of the judge and allowed the innovator a small share of the benefit from the innovation. The risk and low-sharing implicit in this system both inhibited innovation. In sum, although bonus programs to encourage innovation potentially provided cost savings, they could have been structured to provide considerably more.[13]

In sum, the incentives used to motivate Army aviation maintenance supervisors emphasized the central importance of readiness and gave only minimal direct attention to cost reduction. Hence, we were likely to observe large efforts to reduce cost only if they occurred as a by-product of an attempt to enhance readiness.

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[11]It may have had some effect on the assignment of new maintenance duties to a depot. The depots continued to compete vigorously for new activities in spite of their new specialization, but cost affected a small portion of a depot's activities at any time.

[12]Innovations well-tailored to a local shop, of course, were not likely to lead to sweeping cost savings in the Army as a whole. The key point here is that practical improvements constituted one source of innovation worthy of greater attention.

[13]The Army was not unaware of the value of predictable sharing rates. The value engineering program under the Defense Acquisition Regulations (DAR) allowed the Army to share contractor-originated cost savings with the contractor at a rate specified in the contract. DOD usually gave incentives more attention in dealing with outside contractors than in-house. DAPAM 37-4 (April 1976), p. 57; FM 38-34 (October 1969).

CONSTRAINTS ON MAINTENANCE SUPERVISORS

For resource allocation at the level of a distinct organization, one often thinks of constraints in terms of budgets—which determine how much the organization is allowed to spend for inputs—and parametric or exogenously determined monetary prices—which determine how quickly purchases of inputs exhaust the budget. Army aviation maintenance made extensive use of both budgets and exogenous prices, but they bore little resemblance to the budgets and prices economists use to study organizational resource allocation.

Funds from four Congressional budget categories were used in Army aviation maintenance, but a maintenance manager typically had discretion over the use of only one source of funding. Military personnel (MPA) funds dispensed for a maintenance unit were just sufficient to pay the actual military personnel allocated to that unit. Military Construction (MCA) funds, when dispensed, were always tied to specific projects approved by higher headquarters. Other Procurement (OPA) funds[14] were never actually seen at the local level. Higher headquarters used them to buy equipment that was then dispensed to a maintenance activity. Only Operation and Maintenance (OMA) funds were actually given to a local manager for his discretionary use.[15]

As a result, it is not particularly useful to think of funding from MPA, MCA, and OPA in terms of budgets. It is better to think in terms of the fixed set of resources associated with these funds. A maintenance supervisor received not MPA funds but a set mix of military personnel. The funding associated with these personnel was superfluous to the supervisor. Similarly, the supervisor had at his discretion not MCA and OPA funds but buildings and facilities and various specific forms of equipment. Only OMA funds offered opportunities for decisions about resource substitution that characterize an effective budget.

But even the budget associated with OMA funding was unusual. When a maintenance supervisor received OMA funds, their use was typically "fenced" or restricted in several ways. Restrictions increased as we move down the hierarchy. For example, OMA funds for installation shops and military units flowed from Headquarters, Department

[14]OPA funds were also often called PEMA (Procurement, Equipment and Missiles, Army) funds at the operating level.

[15]Indirectly, major procurement and research and development funds also affected maintenance since they funded the aircraft to be maintained. Maintenance requirements were driven by the hardware in these aircraft and a clear tradeoff existed between expenditures on the aircraft and expenditure later on maintenance. This study, by taking the aircraft in a given form, neglects this tradeoff.

of the Army, to HQ FORSCOM in the form of Program 2 or P2 funds. These were allocated to HQ FORSCOM as either "mission" or "base operations" funds.[16] Flying hour funds came down as a separate account within the mission account. These paid for the POL and spare parts consumed in helicopter flight at administratively determined prices. All other OMA funds, allocated to the installation shop, came down as part of the base operations account.

The supervisor has some authority to alter these restrictions slightly. Reprogramming of up to $100,000 of base operations funds was allowed into mission funds at the division level.[17] A section of the base operations account, the engineering accounts,[18] was subject to more severe controls from Congress. The engineering accounts could not be reprogrammed without Congressional notification. Considerable reprogramming required Congressional approval, a costly process.[19]

In sum, even within the OMA budget, a post commander faced several different sources of money. He had not one budget but several, with no way to assure that a dollar from one budget would produce as much for him as a dollar from another. The different budgets actually offered different kinds or "colors" of money with different values.

Resources from any given OMA subaccount or budget were very rarely the only costs a supervisor considered in making decisions to use monies from that subaccount. For example, a supervisor could use OMA funds to buy certain types of capital equipment or to improve facilities (see Appendix C). The monetary list price of this equipment represented only part of the supervisor's total cost of procurement because the approval process imposed large additional costs. The use of OMA funds for investment items sometimes required only local approval. In other cases, a major command or Headquarters, Department of the Army, had to give its approval. When approval from higher headquarters was required, investment could become complicated. For example, requests for equipment costing more than $1000 from either OPA or OMA funds were complicated by the need to get separate approvals for authorizations and funding (see Appendix C). The complexity associated with such approvals delayed the arrival of investment equipment and consumed valuable administra-

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[16]The base operations account was also known as the Z account.

[17]Shifts of more than 5 percent of the budget had to be reported to HQ FORSCOM within a month.

[18]Included were the J, K, L, and M accounts, which were used to fund building maintenance and related activities.

[19]These fences limited a commander's freedom to defer maintenance and divert the funds allocated for building maintenance to activities more likely to enhance his observed performance. Deterioration of buildings occurs slowly; the amount likely to occur during a commander's tenure is minimal, making it difficult to hold him responsible for it. Hence, he was likely to pass the problem on to his successor.

tive resources at the supervisor's disposal. As a result, the supervisor saw the funds committed from his OMA budget as only part of the cost—sometimes only a small part—of acquiring capital equipment through his OMA budget. The real price he paid could be much higher than the administrative price charged against the OMA account. That is, although funding for investment may have come from an OMA account, it was not the only or even the most important constraint governing his decisions about investment.

The supervisor often had some discretion over the future size of his OMA budget. This was particularly important for supervisors of civilian (TDA) shops where local historical costs formed the basis for future budgets. Depots could increase their effective OMA budgets by increasing the monetary price for their services. Conversely, decisions that reduced the resources needed to meet a depot workload, and hence reduced prices, could reduce future budgets. Installations faced a slightly more subtle circumstance because an explicit price was generally not placed on their services. But they too faced the prospect that failure to meet a "required" workload could increase future budgets and successful attempts to exceed the "required" workload could reduce future OMA budgets. Even where a supervisor had complete discretion over an OMA account, that account could constrain his behavior but not in the way that we usually think a budget would.

The OMA constraint on flying hours within the mission account was more familiar. The flying hour budget a division received was the product of the maximum flying hours, by type of aircraft, that division was allowed and an average, fleet-wide flying hour cost.[20] Officials within FORSCOM noted that the divisions found that FORSCOM's average cost was too low and hence that the divisions did not receive enough money to support their authorized flying hour programs. But, because they could not use their own costs to expand their flying hour budgets, they are immediately constrained by the budget. It was effectively beyond their control.

As a general rule, then, OMA budgets provided some degree of discretion and constraint, but not of the kind we are used to seeing in discussions of resource allocation. In fact, the maintenance supervisor faced a series of constraints on specific inputs available to him: facilities, equipment, personnel, and a variety of discretionary OMA accounts. Each of these represents a fixed input available for his use.

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[20]On the basis of requests from the field, Headquarters, Department of the Army, allocated flying hours each year to the major commands. Then, using its average flying hour cost, it determined the budget that would accompany the flying hour authorization. When FORSCOM received its flying hours and budget, it allocated the maximum hours to its divisions and used a FORSCOM average flying hour cost to allocate budgets.

Although the planning function can change these inputs,[21] operations occurred in an environment of fixed aggregate inputs.

From this perspective, the constraints relevant to the maintenance supervisor were not those associated with the budgeting system and their related monetary prices, but those associated with his access to the inputs needed to provide Army aviation maintenance. This perspective, expressed in the form of a central concern over shortages of skilled personnel, test equipment, spare parts, and so on, pervaded the operating level of Army aviation maintenance.

THE CONSTRAINED PURSUIT OF GOALS

Even within the constrained environment planners provided for him, the maintenance supervisor had considerable freedom to operate. In fact, the "shortages" in inputs that he perceived as defining his environment forced him to improvise and innovate to meet his readiness goals. Although this was the environment we observed for Army aviation maintenance in peacetime, it was not totally unlike what we could expect in wartime. Continually changing and unpredictable shortages are the essence of wartime maintenance, calling for local supervisors to be even more flexible and innovative within the constraints that planners "impose."

According to economic theory, when the shop is short of an input, it should treat that input as being more costly and increase its use of other inputs as substitutes. All inputs are in short supply in the sense that the shop may not have infinite, costless supplies of any input. Every input involves a real cost. Where availability is fixed and immutable, its cost is its marginal physical product in its most productive alternative application. For inputs the shop can acquire, the cost is the value of the resources that must be exchanged to obtain these inputs. In sum, a maintenance shop implicitly assigns some notion of cost to every input it uses and chooses mixes of inputs to perform particular tasks by considering their relative perceived costs. The shop's view of relative costs need not be anything like the Army's, DOD's, or society's as a whole. These different audiences will see relative costs in an equivalent way only under the most exceptional circumstances.

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[21]In fact, the supervisor of civilian shops had some discretion over the level of each of these and played an important planning role. Just as he could expand OMA budgets by convincing higher officials that more funding was necessary, he could expand the number of personnel, facilities, and equipment levels. Each involved the administrative costs and delay associated with approval processes in higher headquarters. Appendix C discusses the processes involved.

In the late 1970s, a maintenance shop rarely saw much connection between the monetary price the Army assigned administratively to an asset or skill type and its relative cost within the maintenance shop. Administrative monetary prices were often based on historical cost averages for the Army as a whole. They never considered cyclical or temporary changes in costs over time in response to variations in scarcity.[22] And as noted above, administrative monetary prices did not reflect the full cost of acquiring many assets. For example, from a monetary point of view military personnel were free because a supervisor used no direct discretionary monetary funds to acquire them. But he might indirectly use substantial monetary funds, along with scarce administrative talent, and perhaps some barter, to alter an allocation of military personnel. Such costs never appeared in administrative prices.

Another example would be when a division commander had to decide how to allocate maintenance tasks between his military and civilian shops. The form of the military companies was fixed by a uniform authorizations document within FORSCOM and by an allocation only partially within the commander's control.[23] But the form of the installation shop was much more malleable. The installation commander had considerably more discretion to determine its use of resources. Actual authorizations for personnel were at least partially tailored to the local situation, and the commander could tailor it even more closely by hiring temporary labor and labor under personal services contracts beyond the authorization level. If he was short of labor in military companies, then, he could exploit the installation's mission of supporting military maintenance units and shift the workload toward the installation. In the short run, he could cover this increase with hiring beyond the authorized level; in the longer run, he could use the increased workload to justify more authorizations. This allowed the commander to shift work out of the MPA budget, which he could not change, into the OMA budget, which he potentially could.[24]

A related exchange could be practiced between an installation and depot or a military unit and depot. In effect, the unit or installation shop shifted part of its maintenance load to the depot. Because these FORSCOM shops had to expend OMA funds to perform maintenance and did not pay for depot work, they could conserve their scarce budget. The depot benefited from an increased workload, which it

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[22]Appendix E provides a detailed discussion of problems in three forms of administrative pricing within Army aviation maintenance.

[23]See Appendix D for details.

[24]We observed this practice in the field and were told of other instances.

could use to justify its authorizations or increase them. As a mutual exchange, then, this was likely to occur where the depot was in a better position to affect its authorizations than the installation was because the depot's TDA came from DARCOM and the installation's came from FORSCOM; it could simply be a result of individual managers' abilities and style.

Of course, this kind of behavior did not have to be mutually agreeable to depot and FORSCOM shop; the FORSCOM shops could simply misdiagnose the maintenance required on components they could repair and then ship these components to the depot. They saved the cost of repair.[25] But the turnaround time for the repair was also longer.

A third form of interoffice exchange was important to Army aviation maintenance in the mid 1970s. Aviation companies under the division aviation battalion commander received direct support maintenance from the aviation maintenance company under the maintenance battalion commander in the Division Support Command (DISCOM). This allowed the transfer of unauthorized tasks similar to those in our first two examples, although the similarity of funding and requirements determination in the aviation and maintenance battalions limited the number of opportunities. Under a reform in the late 1970s, the aviation maintenance company in a division ("Company E") was transferred from the DISCOM to the aviation battalion. With aviation and aviation maintenance companies directly under the same commander, unwarranted exchanges of the kind discussed earlier should have occurred less frequently. This organizational change offers an opportunity to test the importance of organizational structures to the conduct of interoffice exchange.

Capital investment offers another example of a resource decision at the operations level. Although a maintenance supervisor often did not have to pay any monetary price at all for capital equipment, the approval process could impose a variety of other costs on him. Perhaps the most important of these was the cost of delay, particularly if the supervisor was a military commander or reported to a military commander. Military personnel usually had a fairly short tenure in any particular position. By the time a commander understood his unit well enough to change its input combination, he did not have enough time left to receive any equipment he ordered. He found himself withdrawing resources valuable to his performance in order to use them to request equipment that would enhance his successor's performance. Of course, a military maintenance commander had no discretion over the capital inputs available to his unit, but a division commander did

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[25]Tasks are shifted from Program 2 to Program 7—wholesale logistics—within OMA funding.

have discretion over the capital inputs his civilian shop used. The Congress imposed strict controls on the engineering accounts within the OMA budget to take this sort of decision out of the commander's hands.

Command emphasis on on-the-job training offers a related example. Military personnel considered good unit performance on annual standardized examinations relevant to their promotion, particularly performance of combat arms. Hence, military commanders had an incentive to provide on-the-job training that assured good performance of combat units. Maintenance units provided the support that was vital to successful unit training over the year. Hence, maintenance support of unit training received considerable command emphasis. But on-the-job training *within* maintenance did not. Although properly trained mechanics could contribute to maintenance support within the division, FORSCOM commanders often found that they lost their trained mechanics to higher priority divisions stationed overseas in higher readiness categories. FORSCOM divisions tended to lose the mechanics they trained before they could get an adequate return on their investment. As a result, scarce maintenance resources flowed directly to the production of maintenance where they could contribute most to the priorities of a FORSCOM division. The costs of maintenance inputs were too high and the benefits too low for the division to justify much on-the-job maintenance training.

These examples first and foremost show that maintenance supervisors did manage their resources within the constraints they faced, and their management yielded some predictable results when we understand their perception of relative costs. A military commander substituted toward civilian maintenance and away from military maintenance precisely because civilian maintenance was less costly to him. Traditional cost analysis as the Army presented it would not yield that result, but the commander knew that such substitution was cost-effective to him because it was easier for him to fulfill his readiness and capability goals. Similar motivations governed the exchange of tasks between depots and installations. The only difference was that two decisionmakers were involved, each apparently finding gains from trade in the exchange arrangements that developed over time.

The investment and training examples offer a slightly different perspective by illustrating that a given set of resources could be used to pursue very different goals. Commanders pursued too little investment and on-the-job maintenance training because they received little benefit from such activities. That does not imply that they were not optimizing or did not have the resources required to "do the job right." It simply means that they did not value these outputs in the same way that the Army did, because the Army gave them faulty signals on how to value these outputs.

These examples reveal that a simple set of difficulties underlies several problems, all of which stemmed from self-interested, rational, and predictable behavior by maintenance supervisors and their supervisors.[26] These supervisors were responding to the signals the Army aviation maintenance system gave them about its apparent priorities. The problems emerged and persisted because these signals did *not* in fact reflect those priorities.

One simple way out is to suggest that many of these problems could be eliminated if investment, training, and other decisions were based on appropriate cost-benefit studies. These examples further illustrate why Army maintenance personnel had little faith in such analysis as traditionally conceived. Such analysis used administrative levels of prices, which had little or no connection to the relative costs relevant to decisionmakers within Army aviation maintenance.[27]

We can now understand why the Army restricted economic analysis to noncombat activities. How could such analysis possibly represent such costs in wartime? And why should cost savings be valued in efficiency reports when the probable method of measuring savings would say nothing about how well a commander managed the relative scarcities of inputs in a particular situation?

More generally, even if traditional economic analysis did reflect the Army's goals, we can understand Army officials' lack of faith in it. What can a 10 percent real cost of capital mean to a commander who needs a two year payback period to justify an investment to himself?

The economic perspective on resource allocation in Army aviation maintenance tells us that aviation maintenance operations looked more like a small, complex economy than like the organization suggested by the traditional theory of the firm. Army aviation maintenance shops performed their operations within a fixed set of inputs. Just as in an economy, the process of converting these inputs into valued outputs yielded a set of "shadow prices," which defined the relative costs of these inputs.[28] Such shadow prices emerged from the implicit optimization activities of the Army's maintenance supervisors. For such a production activity to relate its input use to

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[26]Restrictions on engineering accounts and the change in Company E illustrate that the Army did understand specific instances of such behavior.

[27]Cf. Klaus (1974), which found that the principal reason cost analysis was rare at the operating level in the Army was because local managers lacked the proper incentives to use it.

[28]An input's "shadow price" is the value of the product that one additional unit of input could provide if the maintenance shop had an additional unit. Hence, it represents the cost—the forgone benefit—of using *any* unit of this input. The higher its shadow price, the more a maintenance shop would presumably be willing to pay to relieve its shortage of this input.

the relative availability (cost) of inputs in the economy as a whole, it had to be able to relate these shadow costs from actual practice to relative prices of these inputs in the market place. The Army did this only in the crudest manner.

IMPLICATIONS

At the operations level, Army maintenance supervisors saw their principal resource allocation problem not as one of reducing costs but as one of coping with persistent input shortages. If anything, cost reduction was a luxury that had to take a lower priority than providing readiness and capability in the face of these shortages. In our framework, coping with shortages is equivalent to reducing costs. Getting the most output from a given set of inputs is equivalent to minimizing the levels of inputs needed to produce a given set of outputs. Hence, despite the apparent lack of interest in cost reduction shown by Army supervisors and documents, a strong motive remains for using a cost framework to manage Army aviation maintenance when a maintenance unit has difficulty meeting its output goals.

The verb "to manage" is important. Local maintenance supervisors are managers, not the administrators envisioned by Army doctrine, precisely because that doctrine does not permit local supervisors to meet their readiness and capability goals with the available resources. This is important for two reasons. First, the shortages local managers face differ from one post to another, but, *taken as a whole,* they are not arbitrary. They reflect shortages in the economy that are not fully recognized in Army doctrine. That is, local experience in individual shops contains information about the Army's general resource environment. It could be extremely valuable to planners if they could find a way to detect and gather that information. Second, if managers face troublesome shortages in peacetime, they can only expect a worse environment in wartime, especially under prevailing views of the next war, in which the Army must fight with whatever it has available when the war starts. Better understanding of how to manage resource shortages in peacetime should increase the Army's ability to manage them in wartime both by improving the processes Army supervisors use to manage *any* shortage and by finding better ways to anticipate and quantify the effects of shortage in wartime and prepare for them.

In sum, understanding shortages in a cost context should help Army operators and planners pursue both peacetime and wartime goals. The concern in this report is peacetime resource allocation. Giv-

en that peacetime is to a large extent simply a period in which the Army prepares for war, however, any discussion of peacetime resource issues must keep wartime needs close at hand.

A cost framework better suited to actual operating decisions in Army aviation could help Army planners "close the loop" on planning activities by providing a simple way to view how plans affect operations in peacetime. That is, local practice offers a basis for understanding all of Army aviation's operating environment in peacetime. Currently, pursuit of local goals and unintentionally perverse information on resource costs to the Army as a whole lead to unusual local practices. A better cost framework could allow planners to understand local practices better and to sort those of only local interest from those that reflect changes important to the Army. In particular, better cost analytic tools could allow local commanders to quantify their existing shortages and, hence, communicate information on these shortages to planners in an economical form. They could help local managers to deal with resource shortages more effectively, and they could help planners better understand the decisions that local managers make and design regulations assuring that these managers' new tools are used to the Army's best advantage.

The basic notion here is that, in an organization as complex and heterogeneous as the Army is, different aspects of the organization's changing environment will probably first be noticed by individual offices within the organization whose managers realize that their operating environment has changed. That is, information about change will always be present within the organization but will appear first in its operating shops. In this sense, organizations may be closer to reality than their policies indicate. And to the extent that this is true, "organizations may be capable of more flexibility and adaptability than observers expect. Planners then must resolve the problem of discovering the degree of organizational fragmentation on any given issue and of trying to tap the flexibility implied by its existence" (McNaugher, 1980).

For example, the manpower shortages that maintenance supervisors perceived in local shops mirror the manpower shortages in the economy as a whole, both in the aggregate and with respect to individual skills. The fact that the cost of labor has risen so high relative to that of capital since World War II is equivalent to the notion that labor is becoming increasingly less available to *all* activities in the economy. The real productive value of labor—its shadow price—continues to rise. Specific shortages in individual maintenance shops throughout the Army have signaled the growing difficulty of obtaining manpower, not just in the Army but everywhere. They demand that the Army reduce its reliance on labor inputs and shift it elsewhere, just as activities elsewhere in the economy have done routinely.

In practice, the Army was doing that in the late 1970s because it could not relieve its shortages of many skills. Planners could have learned a great deal about how the Army's operational managers were achieving this substitution away from labor by explicitly setting up their information systems to detect and learn from this behavior. As noted in the last section, Army doctrine discouraged planners from paying close attention to the specific nature of deviations from their prescribed practice because they did not believe the relative peacetime availabilities of inputs would persist into the wartime environment in which their organizations must excel. That consideration is likely to be more important in some cases than in others. The available evidence suggests, for example, that the scarcities of labor we observe in our peacetime economy will not fade away in wartime.[29]

In general, local maintenance shops offer the Army natural experiments in the provision of maintenance. That the Army has typically tested new organizational and weapons concepts at individual posts before accepting them suggests that Army planners have been well aware of the potential for experimentation. Hence, one could think of *each* post as a continuing experiment in organizational concepts formulated by many managers throughout the Army.

Gathering information from so many individual experiments and making sense of it will be extremely difficult unless simple and meaningful summary statistics can be devised to transfer information to both local managers and planners. Prices serve this purpose in a free market. Appropriate information on costs could do so within Army aviation, but it will not be available unless local managers can generate cost information relevant to their highly constrained operating circumstances. An experimental Army program was begun in the 1970s, and it could provide the basis for a cost system that allowed managers to do that.

FORSCOM's experimental Training Management Control System (TMCS) gave battalion commanders at Ft. Carson a linear programming model that defined an objective function in terms of priorities on different training activities throughout the year. The model maximized a commander's self-specified objective function in the face of such resource constraints as flying hours, POL, ammunition, repair parts, and availability of the training area. The commander's current and cumulative financial situations were recorded throughout the fis-

[29]For example, the pool of eligible young people on which the Army has traditionally depended for its enlisted force will actually drop in absolute size during the 1980s. This is a physical constraint that cannot be avoided in wartime or peacetime.

cal year, allowing him to reprogram activities as his mission status changed.

The experimental program offered two basic benefits. First, it allowed the commander to perform certain comptroller functions for which he previously had neither the capability nor the time. Second, it offered the Army a first-time opportunity to calculate the costs of specific activities in its training programs on the basis of experience.

Immediate superiors were not allowed to monitor subordinate commanders' programs or evaluate them on this basis. This could have led to information distortion in the programs by subordinates and neutralization of the usefulness of TMCS as an effective management tool. The experiment was in progress during our field work; no evaluations were then available.

This experimental program raises some important points about the relationship between cost information and incentives. If a local manager is to take serious advantage of a costing tool, he must believe it will serve his needs. As we have seen, local managers care about readiness and, so long as they are having difficulty meeting their readiness goals, will be interested in any tool that increases their ability to use the resources at hand. The TMCS recognizes the character of the local commander's problem and is likely to interest him. It serves *his* needs, although not necessarily the Army's or society's at large. A local manager will not take any other type of costing aid seriously.

Data relevant to planners may well be distorted if they must also be reported to a manager's supervisors. Supervisors traditionally prefer the administrative to the managerial model of their subordinates.[30] This leads supervisors to seek conformance with their orders in the actions of their subordinates; and it leads subordinates to report conformance to the full extent possible. Planners are more interested in variation where it actually exists. They want to see variation both to reap the benefits of the many experiments they are overseeing where such benefits can be established and to understand the extent to which the command mechanisms they have designed are actually achieving their intended results. In sum, if the data planners collect from local maintenance shops are to prove useful, they must be withheld from higher-level managers responsible for judging performance of these shops.

Planners must fully understand that giving a local commander a better ability to understand costs and thereby to deal better with his resource shortages will also give him a better ability to pursue his own goals. This is true whether his goals are consonant with the

[30]Cf. Hitch and McKean (1965), p. 237.

Army's or not. It need not imply that local commanders pursue plans to benefit themselves personally. They could easily overemphasize the extent of their activity's needs and importance relative to those of the Army's as a whole; they might even misinterpret the Army's broader goals and fail to pursue them despite their best efforts. The point here is that giving local supervisors a better capability to manage resources gives them greater power, for good or bad. It recognizes that they are more managers than administrators. Planners and managers must be prepared for this increase in local capability. Properly implemented, it should provide information in a form that allows planners to articulate the Army's resource goals more precisely and thereby increases the consonance of local supervisors' goals and those of the Army. That is, planners can pursue conformance between higher-level supervisors' objectives and local practice *indirectly* by seeking conformance in objectives at the highest levels of the Army and in the maintenance shops instead of *directly* by seeking conformance between regulation and audited practice.

In sum, a cost framework better suited to actual operating conditions in Army aviation could simplify the process of gathering data on local practice during peacetime. Planners could "close the loop" more completely in their peacetime planning process only if the Army gives greater emphasis to the role of local supervisors as managers and, in particular, gives them greater capability to manage resources. How successful such a change would be is an empirical question, but it holds such promise that it warrants closer attention.

Peacetime, of course, covers only one part of Army aviation's resource allocation problem. Ever present in every maintenance supervisor's concerns and, in particular, in Army doctrine, is the fact that Army aviation maintenance activities exist to wage war if necessary. Although a better understanding of options for managing resource allocation in peacetime can help Army planners improve aviation maintenance in peacetime, it is far from clear—especially to Army maintenance managers—how such an understanding can help them prepare for their wartime roles.

As we have noted several times already, so long as managers have difficulty achieving their objectives with the resources at their disposal, cost minimization can enhance their performance, no matter what their immediate objectives are. In wartime it will become increasingly difficult to realize objectives with the resources available. Proper management of resources in peacetime can help alleviate the effects of resource shortages in wartime in two ways. First, better resource management will increase the Army's understanding of basic resource shortages in the economy as a whole—shortages that will persist in wartime. This will allow the Army to design organizations with

greater attention to its ability to achieve the designs promulgated in actuality. Second, the process of managing scarce resources in peacetime should improve Army managers' abilities to manage even scarcer resources in wartime. These improved abilities would be embodied in organizational design and reflected in managers' enhanced skills at allocating resources within any organization design.

Shortages experienced in peacetime are relevant to wartime most obviously because current doctrine envisions a "come as you are" war scenario in which we fight the war with whatever resources are available. Most studies to date concerned with the transition from peacetime to wartime under such a scenario have emphasized the need to reflect wartime consumption and casualty rates in peacetime stockpiling and planning.[31] This might be called the "demand side" of the transition because it emphasizes the military demand for resources over the transition. On the supply side, wartime resources must be provided in a peacetime economy from resources available in that economy. That is, peacetime prices for resources reflect their relative scarcities in the peacetime environment. To make the most of resources purchased for wartime *during peacetime,* the Army must understand their relative scarcities in the economy it draws on in peacetime and, hence, their relative costs in *any* case, including preparation for war. Such relative scarcities will probably come to the Army's attention in its actual peacetime operations.

Another reason shortages in peacetime are relevant to wartime planning depends on a more prolonged war scenario—for example, one more like the military undertakings in Korea and Vietnam. Under such scenarios, the civilian economy is heavily affected by military demands for labor and other resources, but it continues to look in many ways like a peacetime economy. In particular, peacetime prices of many goods do not change because their relative scarcities in the economy as a whole do not change. As the military action takes a larger and larger share of national resources, the length of military action falls and we move closer to a short war scenario like that discussed above. Economic conditions will be different from peacetime conditions before the war but not that different. We cannot simply project what we learn about the relative costs of resources during peacetime into the wartime period, but we presumably learn a great deal about probable conditions.

Taken together, these two cases suggest that the military will probably have only a limited claim on the civilian economy for the resources it actually uses to make war. This becomes less reasonable as a large, long war becomes more likely; but this only makes the inter-

[31]For example, see the excellent work in Shishko and Paulson (1979); Palmer (1976).

pretation of peacetime data more difficult, not irrelevant. Given the gross scarcities every military commander knows will come with war, opportunities to foresee those scarcities and find better ways to plan for them should look fairly attractive.

In addition to improving the Army's understanding of probable economy-wide scarcities of resources in wartime, peacetime attention to costs and resource management can enhance the process the Army uses to allocate resources in wartime. It will both improve the design of organizations to manage shortages and sharpen the skills of managers in any organization for handling shortages they experience.

Organizational forms to improve the management of shortages can take many forms. The simplest is the creation of greater analytic capability at the operating level. This includes, at the very least, better training of operating managers in the use of costing tools. It could also involve the creation of new positions and even new shops with analytic capability at the operating level. The more difficult organizational change, however, is one that ensures local supervisors use such new capabilities to the Army's best advantage (cf. Klaus, 1974). Such capabilities and the motivation to use them seriously must be developed in peacetime if they are to be ready for the time when they will be of greatest importance.

Even if organizations do not change, more attention to resource management in peacetime will help prepare Army supervisors for their roles in wartime. The notion is really no different from that of on-the-job training, military exercises to keep military skills intact, and flying hours to maintain pilot skills. The wartime commander will have little time to think of creative ways to change his routines. If he is to use cost tools successfully in wartime when his need to manage shortages will be greatest, he must have familiar routines for doing so, so that he can call on them without difficulty. For example, if the TMCS device discussed above becomes a routine part of a commander's capability, he should be able to use it to manage resources in combat as well as in the training exercises that presumably resemble combat.

Both organizational changes and the simple development and maintenance of skills that enhance local supervisors' abilities to manage shortages are more likely to be of value in wartime the more the shortages they actually cope with in peacetime resemble those they will see in combat. This point is not lost on Army officials. Many Army officials commended the once-monthly form of readiness reporting used until 1978 because it induced a monthly surge in maintenance that helped prepare military units for surges of demand and their associated shortages in wartime (see Appendix C). A more extensive form of this "simulation" of war could include periodic short-

ages or price changes for various inputs that would force units to adjust. Many would argue that this happens in Army aviation maintenance and elsewhere today. But the current "simulation" is lacking because Army information systems are not well-designed to observe responses to such shortages and current shortages need not have any relationship to shortages that will be faced in wartime, particularly in a short, intense war.

It is beyond the scope of this report to suggest how managers might respond to shortages, but a place to start is with war simulations planners use to prepare for war. To the extent that they are appropriate for planners, they also include information operators should use to learn how to manage the resources they will actually have under current plans.[32]

The pervasiveness of perceived input "shortages" in Army aviation maintenance and the importance of dealing with these at the operating level suggest that a better understanding of actual relative input costs can enhance the provision of maintenance in peacetime and wartime. Such an understanding can increase local supervisors' abilities to manage peacetime shortages and increase planners' ability to learn about peacetime resource constraints of importance to the Army as a whole by observing local practice. It can generate data that planners can use to adjust both the resources authorized for maintenance organizations and the Army's regulations and other controls on the use of these resources to changing circumstances. And, in all likelihood, it can help operators prepare for the types of resource shortages likely to characterize wartime. Over time, these applications could enhance the Army's ability to respond to changes in relative input prices with improved resource use in wartime and peacetime.

[32]One technique for relating Army planning assumptions to resource issues is discussed in Shishko and Paulson (1979).

V. CONCLUSIONS

Army aviation maintenance responded very slowly to changes in relative input prices in the late 1970s. Our examination of planning and operating functions in Army aviation maintenance suggests that several factors, many of which may be important in other Department of Defense activities, contributed to its slow response. We have determined five pertinent conclusions:

1. The Army could and did substitute among inputs without changing aircraft. A common view among Army aviation maintenance personnel was that the best way to substitute away from increasingly costly labor was to design new aircraft that require fewer maintenance labor inputs. Although the Army has clearly pursued this option vigorously, it was not the only one, and it was not necessarily the best one. The Army has usually needed more than ten years to design and introduce a new aircraft. At the 10 percent real cost of capital OMB prescribes, $1 saved through such an introduction is worth an investment of less than $0.35 at the start of the introduction. Because organizational changes can potentially be achieved far more quickly than changes in aircraft, the savings that result from them can justify much higher investment costs per dollar.

Part of the Army's enthusiasm for new aircraft as an option derives from the view that because requirements for inputs were often expressed as fixed input-output coefficients, coefficients represented the best way to provide maintenance. Our examination suggests that was not the case. Many substitutions among inputs were possible within Army maintenance shops, between them, and between them and other activities in and out of the Army. Considerable evidence of such substitution was visible in actual Army maintenance operations. Unfortunately, Army information systems were not designed to discover the specific nature of such substitutions. And because local shops did not price inputs to reflect their relative costs in the economy as a whole, they by themselves could not achieve the input substitutions of greatest value to the Army. Greater high-level understanding of substitutions actually executed in Army maintenance shops could increase the Army's confidence in planning for input substitution and increase its interest in detecting and responding effectively to changing relative input prices.

2. The cost of collecting valid resource information on current experience discouraged its use. Army aviation maintenance used many information systems to monitor the status of current operations. Some,

like those designed to track the status and location of individual aircraft or to assure flying safety, received high command emphasis and performed quite well. Those systems monitored objective data whose validity could easily be audited and whose lack of validity could precipitate serious consequences, including the death of pilots.

Other systems—those designed to collect cost data among them—were less successful. Local supervisors had little incentive to report data into these systems properly; they often grossly overestimated costs. It would be extremely difficult and costly to detect and correct specific cases of misreporting. Army planners recognized the general problem and gave little credence to the data these systems reported, leading to a loss of command emphasis for these systems and even less enthusiasm for reporting accurate data locally.

Unfortunately, these systems offered the Army its only comprehensive data on actual current experience with resource use. That is, high-level Army planners had very little reliable information on the Army's actual use of resources at the local level. Given the common belief that peacetime experience could not accurately reflect the needs of wartime maintenance, planners may have been reluctant to incur serious costs to collect data on peacetime operations. However, they thereby missed a chance to detect systematic changes in relative input prices.

This absence of information caused high-level planners and lower-level operators to have different views of difficulties in the Army. Planners were future oriented and based reforms for the future on circumstances in the past when they were operators. Operators had a better empirical understanding of current problems but little perspective with which to understand their causes or interconnections.

3. Many Army problems stemmed from local misperceptions of input costs. Simply because Army planners could not monitor or even measure the costs of inputs perceived at local maintenance shops did not mean that such costs did not affect Army aviation maintenance. Both military and civilian supervisors overvalued capital relative to labor at any reasonable valuation of their relative costs; hence, they were reluctant to substitute capital for labor. Similarly, military shops viewed all of their resources as being costlier than civilian shops believed theirs were even when no objective differences could be seen; hence, supervisors substituted maintenance production out of military and into civilian shops.

All of these individual problems are simply manifestations of a single phenomenon: Individual offices within Army aviation perceived costs of inputs and services that differed from those the Army (or society as a whole) perceived. A better understanding of relative input scarcities perceived at the local level, particularly if it leads to quan-

titative measures of the perceived costs of these scarce inputs, could markedly reduce the cost of conveying data to planners on actual operations. These data in turn could contribute greatly to the resolution of some of these problems.

Better measures of relative input scarcities at the local level could also increase the ability of local supervisors to pursue their own goals, thereby creating new problems for Army aviation maintenance if such goals were not consistent with Army-wide objectives. Hence, any program to give local supervisors management tools that enhance their ability to allocate local resources must be accompanied by programs to monitor the actual allocations they choose. Better management tools enhance the abilities of both operators and planners to pursue their goals. Over time, better management tools can improve operations and planning jointly only if planners recognize the inherent adversary role between themselves and operators and use it constructively to improve their control over the actual products of maintenance. This promises sufficient benefits to warrant closer examination.

4. *A greater concern for resource costs could have helped the Army organize for wartime.* Most Army officials shared a common concern that their missions were important only to the extent that they were prepared to fight and win a war. Hence, the organizations they planned and commanded had to be designed to fight and win a war. These beliefs were obviously correct, although a careful look at how organizations were actually designed raises serious doubts about how well they reflected probable wartime requirements. These beliefs also often carried with them an implicit corollary that cost concerns were peacetime concerns. According to this view, national defense was the premier national priority in war, and cost concerns would not hinder the nation's determination to win. Hence cost concerns and the economic analyses associated with them were of questionable validity in planning combat organizations. This point of view underemphasized the scarcity of inputs in combat organizations during wartime. Properly conducted, economic analysis can help plan for coping with the scarcities of inputs that will become a commander's most difficult resource problem in wartime.

5. *Better response to changes in input prices should on net benefit the Army.* Resource allocation mechanisms in the Army were unresponsive to changes in the relative prices of inputs the Army uses. This lack of responsiveness persisted because planners and operators in the Army saw no benefits in ending it. The data we have collected in the field point to an internally consistent view of the world within Army aviation maintenance. No part of it can be altered without having first changed the other parts:

> Relative input costs are not very important to organizational design because few options are feasible for maintaining current models of aircraft. Hence, cost data are more important for estimating budgetary requirements than for choosing among organizational designs. Because we are planning for war, costs are not of primary importance to planning manpower and equipment requirements. Peacetime cost data are of only limited usefulness in defining worthwhile needs anyway, so cost information systems do not require command emphasis. With the limited information available in peacetime, personal experience is an important source of information on how to combine manpower facilities, equipment, and inventories to produce Army aviation maintenance.

The result in the late 1970s was many problems that could well persist and even get worse as changes in the external economy from which Army aviation maintenance draws its inputs outpace the Army's ability to respond.

To maintain its effectiveness in a dynamic world, the Army must learn how to respond to the continual changes in the prices and availability of its inputs. It can do so only by breaking the grip that this view has on its practice of organizational design. Our analysis suggests that one place to start is a reevaluation of cost concepts making it attractive to the Army to exploit data on current practices of resource use in its maintenance shops. The same probably applies to other activities in the Department of Defense as well.

Appendix A

GLOSSARY

AAA	Army Audit Agency
AAH	Advanced attack helicopter
ACE	Aircraft Evaluation (Team)
ACIMS	Aircraft Component Intensive Management System
ADP	Automated data processing
ADPE	Automated data processing equipment
AH-1G	Huey Cobra attack helicopter
AH-1Q,S	Cobra-TOW attack helicopter
AIF	Army Industrial Fund
AIMI	Aviation Intensively Managed Items
ALMC	Army Logistics Management Center
ALO	Authorization level of organization
ALRES	Army Logistics Readiness Evaluation System
AMC	Army Materiel Command
AMETA	Army Management Engineering Training Agency
AMMC	Army Maintenance Management Center
AMMH	Annual maintenance manhours
AMS	Army Management Structure
AMSAA	Army Materiel Systems Analysis Activity
ARCSA III	Aviation Requirements for Combat Structure of the Army
AR	Army Regulation
ARMCOM	Armaments Materiel Readiness Command
ARMS	Aviation Resources Management Survey
ASARC	Army System Acquisition Review Council
ASL	Authorized Stockage List
ASPR	Armed Services Procurement Regulations

AVIM	Aviation Intermediate Maintenance
AVRADCOM	Aviation Readiness and Development Command
AVSCOM	Aviation Systems Command
AVUM	Aviation Unit Maintenance
BITE	Built-in test equipment
BOIP	Basis of Issue Plan
CAA	Concepts Analysis Agency
CAC	Combined Arms Center
CAMMS	Corps Automated Maintenance Management System
CAMUS	Commitment Accounting and Management of Unit Supplies
CCAD	Corpus Christi Army Depot
CEDRS	Capability Engineering Data Reporting System
CEMPR	Command and Equipment Management Program Review
CEP	Civilian Employment Projection
CERCOM	Communication Electronics Command
CH-47A,B,C	Chinook cargo helicopter (medium lift)
CH-54A,B	Tarhe cargo helicopter (heavy lift)
CLRT	Command Logistics Review Team
CMS	Common maintenance supplies
COA	Comptroller of the Army
COMET	Command Maintenance Evaluation Team
CONUS	Continental United States
CORADCOM	Communications Research and Development Command
CS_3	Combat Service Support System
CTA	Common Table of Allowance
DA	Department of the Army
DAMPL	Department of the Army Master Priority List
DAPAM	Department of the Army Pamphlet
DARCOM	Materiel Development and Readiness Command
DCSLOG	Deputy Chief of Staff, Logistics
DCSOPS	Deputy Chief of Staff, Operations

DCSPER	Deputy Chief of Staff, Personnel
DCSRDA	Deputy Chief of Staff, Research, Development, and Acquisition
DESCOM	Depot Systems Command
DIMAS	Directorate of Management Information Systems
DIMES	Defense Integrated Management Engineering System
DIO	Director of Industrial Operations
DIPEC	Defense Industrial Plant Equipment Center
DISCOM	Division Support Command
DLOGS	Division Logistics System
DLSIE	Defense Logistics Studies Information Exchange
DMPE	Depot Maintenance Plant Equipment
DMWR	Depot Maintenance Work Requirement
DOD	Department of Defense
DPAMMH	Direct productive annual maintenance manhours
DS	Direct support
DX	Direct exchange
ECOM	Electronics Command
ECP	Engineering Change Proposal
EDRE	Early Deployment Readiness Evaluation
EIR	Equipment Improvement Request
EST	Equipment Survey Team
FHP	Flying hour program
FMT	Field maintenance technician
FORSCOM	Forces Command
FSC	Federal stock classification
FSN	Federal stock number
FST	Field supply technician
GAO	Government Accounting Office
GS	General Schedule
GS	General support
HQ	Headquarters
HQDA	Headquarters, Department of the Army

IDSM	Integrated direct support maintenance
IET	Industrial engineering team
IG	Inspector General
ILS	Integrated Logistics Support
IPAMMH	Indirect productive annual maintenance man-hours
IR	Internal Review
ITDT	Integrated Training and Documentation Technique
LAO	Logistics Assistance Office
LEA	Logistics Evaluation Agency
LOGC	Logistics Center
LOGMAP	Logistics System Master Plan
LSA	Logistics Support Accounting
LSAR	Logistics Support Accounting Report
LSSA	Logistics Systems Support Agency
M&S	Methods and Standards
MAC	Maintenance allocation chart
MACOM	Major command
MACRIT	Manpower Authorization Criteria
MAIT	Maintenance Assistance and Instruction Team
MCA	Military Construction, Army
MCS	Maintenance Control System
MD	Maintenance Directorate
MIDA	Major Item Data Agency
MIRCOM	Missile Materiel Readiness Command
MIS	Management information system
MOS	Military occupational specialty
MPA	Military Personnel, Army
MRA&L	Manpower, Reserve Affairs & Logistics
MRC	Materiel Readiness Command
MRSA	Materiel Readiness Support Agency
MSC	Major subordinate command
MSG 2	Maintenance Specification Guide 2

MST	Manpower Survey Team
MTOE	Modification Table of Organization and Equipment
MTS	Man year
MWO	Modification Work Order
NCO	Noncommissioned officer
NICP	National Inventory Control Point
NMP	National Maintenance Point
NOE	Nap-of-the-earth
NORM	Not operational for reason of maintenance
NORS	Not operational for reason of supply
O&S	Operating and support office of the Assistant Secretary of Defense
OCAR	Office, Chief of the Army Reserve
OCM	On-condition maintenance
OH-6A	Cayuse observation helicopter
OH-58A	Kiowa observation helicopter
OJT	On-the-job training
OMA	Operation and Maintenance, Army (also O&MA)
OMAR	Operation and Maintenance, Army Reserve
OMB	Office of Management and Budget
OPA	Other Procurement, Army
O&S	Operating and support
OSD	Office, Secretary of Defense
PB/AESRS	Property Book/Army Equipment Status Reporting System
PE	Program element
PEMA	Procurement, Equipment and Missiles, Army
PI	Profile Index
PIP	Product Improvement Proposal
PLL	Prescribed Load List
POL	Petrol, oil, and lubricants
POM	Program Objective Memorandum
PPBS	Program Planning Budgeting System

PRON	Procurement Order Number
PSR	Project Status Report
P2	Program 2 (general purpose forces)
P7	Program 7 (central maintenance and supply)
P7M	Central maintenance
QDR	Quality Deficiency Request
QQPRI	Quantitative, Qualitative Personnel Requirements Information
RAM	Reliability, availability, maintainability
RCM	Reliability-centered maintenance
RCMS	Reliability-centered maintenance strategy
SAAD	Sacramento Army Depot
SAG	Study Advisory Group
SAILS	Standard Army Intermediate Logistics System
SALS	Standard Army Logistics System
SAMS	Standard Army Maintenance System
SBA	Small Business Administration
SIDPERS	Standard Installation/Division Personnel System
SMMS	Standard Materiel Management System
SOCAR	Statements of Conditions and Recommendations
SPARC	Spare Components Requirements for Combat
STANFINS	Standard Army Financial System
TAERS	The Army Equipment Reporting System
TAMMS	The Army Maintenance Management System
TBO	Time between overhauls
TDA	Table of Distribution and Allowances
TDY	Temporary Duty
TH-1G	Attack trainer helicopter
TH-55A	Osage helicopter trainer
TI	Technical inspector
TLRS	Total Logistics Readiness Sustainability
TMCS	Training Management Control System
TMDE	Test, measurement, and diagnostic equipment

TOE	Table of Organization and Equipment
TRADOC	Training and Doctrine Command
TROSCOM	Troop Support Command
TSARCOM	Troop Support and Aviation Readiness Command
TSM	TRADOC Systems Manager
UE	Unit equipment
UH-1B,C,D,H,M	Iroquois utility helicopter
UIC	Unit identification code
USAAVS	Army Aviation Safety Board
WARPAC	Wartime Unit Consumption Guides
WB	Wage Board

Appendix B

THE ORGANIZATION OF ARMY HELICOPTER MAINTENANCE

Helicopter maintenance was a major activity within the Army in the late 1970s. It accounted for almost 16 percent of all Army maintenance and about the same proportion of active Army maintenance.[1] This involved over 18,000 military mechanics alone and 8,376 helicopters of four types.[2] Table B.1 lists the types of helicopters used and maintained.[3] This appendix briefly reviews the organization of Army aircraft maintenance.

CATEGORIES: THE ARMY VIEW OF MAINTENANCE

The Army maintained most helicopters within a four-level or four-category maintenance system during the late 1970s, but helicopter maintenance in Europe applied a three-level concept developed in Vietnam. This system was shortly to replace four-level maintenance for all nonavionics tasks.[4]

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[1]These measures are based on the numbers of enlisted mechanics in different Army maintenance activities. It is obviously a very crude measure, neglecting as it does differential capital-labor ratios and skill mixes across activities and civilian maintenance shops. The specific numbers used are numbers of active operating personnel in various maintenance military occupational specialties (MOSs) and numbers of mechanics in various types of reserve and National Guard units in FY 1977. Narragon, Neil, and Wilk (1977) report these numbers.

[2]According to Corpus Christi Army Depot, this was the inventory on 31 March 1977.

[3]The UH-60A Blackhawk is now being introduced to replace the UH-1; the YAH-64, now in development, will be introduced soon to replace existing attack helicopters.

[4]As should become clear, a production environment like that in Fig. 2 existed for each category of maintenance. To the extent that one category directly supported another, shops in the first could be viewed as providing inputs to those in the second. The Army often defined its levels of maintenance in different ways, depending on the context of discussion. For example, the "organizational" level in Fig. B.1 was often called the "user" level. The "general support," "direct support," and "organizational" levels were occasionally addressed jointly as a "retail" level, while the "depot" level was "wholesale" level. And sometimes a "national" level was imposed above all of these at the Department of the Army (HQDA) level.

Table B.1

HELICOPTERS IN THE ARMY INVENTORY IN 1977

Designation	Name	Use	Number
Attack			
AH-1G	Cobra	fire support	458
AH-1Q,S	Cobra-TOW	antiarmor	242
TH-1G	—	trainer	34
Cargo			
CH-47 A,B,C	Chinook	medium lift	452
CH-54 A,B	Tarhe	heavy lift	73
Observation			
OH-6A	Cayuse	light observation	418
OH-58A	Kiowa	light observation	2046
Utility			
UH-1B,C,D,H,M	Iroquois	troop transport, fire support, general utility	4046
Trainer			
TH-55A	Osage	trainer	607

SOURCE: Corpus Christi Army Depot. The numbers are current as of 31 March 1977.

Four-Category Maintenance

Most helicopters in CONUS were maintained under the standard Army four-category maintenance concept. This called for depot, general support, direct support, and organizational levels of maintenance. (See Fig. B.1.) Army Regulation 750-1 (May 1978) defined in considerable detail what specific maintenance activities were included in each category. Even more detailed listings of specific tasks in each category were listed in a Maintenance Allocation Chart (MAC).[5] A MAC existed for each type of helicopter.

Generally, tasks whose production characteristics displayed greater economies of scale in equipment or labor skills were placed at higher

[5]The technical manual for each Army equipment type included a MAC that dictated the highest level at which any maintenance action might be performed. In assigning tasks to categories, the Army considers the time required for performing the maintenance action, the availability of requisite technical skills, tools, test equipment (TMDE), and other support equipment as authorized in tables of organization and equipment (TOEs). It presumably also considered the cost of assigning a task to one category rather than another.

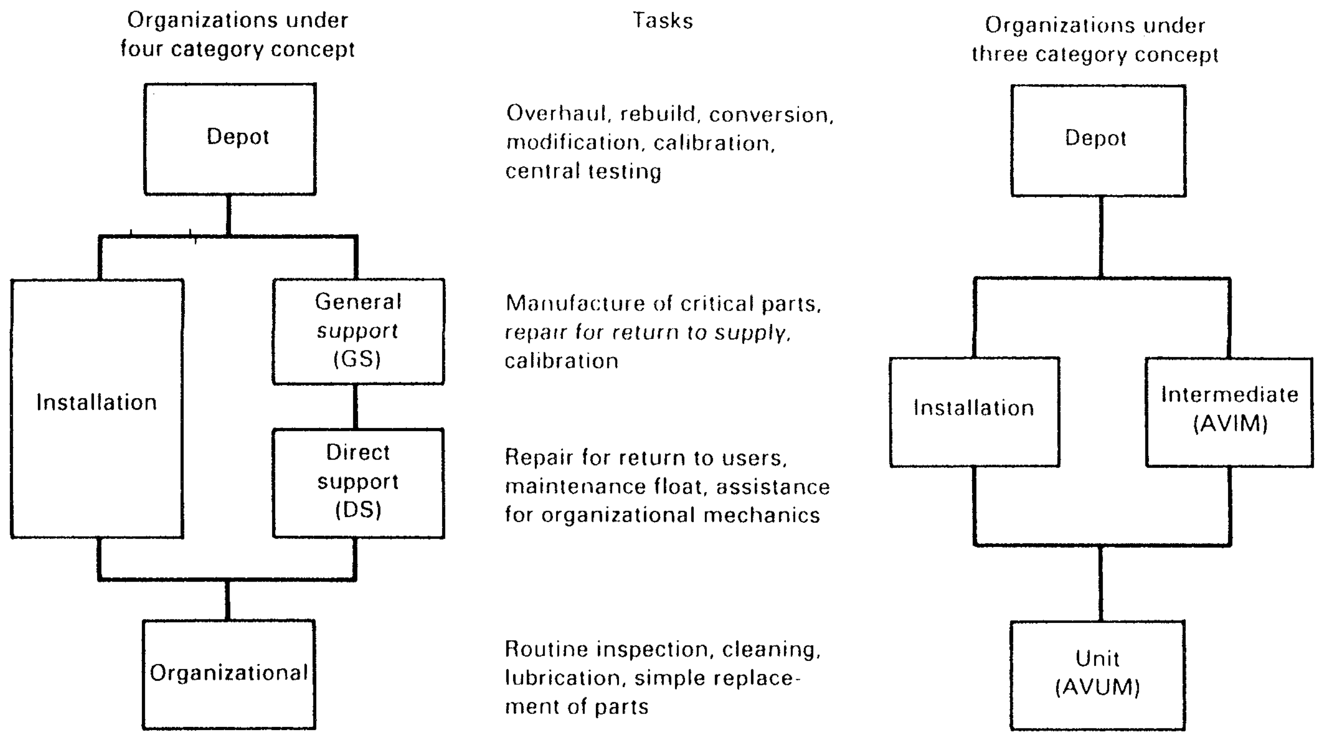

Fig. B.1—Organization of Army aviation maintenance

levels—closer to the depot. Suppose a person with a special skill would be fully employed only if the full Army helicopter fleet generated his workload. Then the task he did should be performed at the depot. Less specialized tasks could occur lower in the maintenance ladder. Depot maintenance involved overhaul and rebuild, conversion and modification,[6] and calibration of helicopter airframes and components. Helicopter depots also provided certain central testing services. Oil analysis, for example, applied forensic techniques to oil samples from individual helicopters on a regular basis to predict imminent failures. The depot provided specialized oil analyses. Calibration of diagnostic and other ground support equipment is another.

General support (GS) and direct support (DS) maintenance were usually combined in the other services and were called intermediate maintenance. The Army differentiated them to provide better maintenance service to front line combat units. In combat, the Army was more mobile than the other services. Maintenance was best provided by using both mobile DS shops and fixed GS shops. The DS shops provided on-site repair service with both shop locations near combat units and contact teams of mechanics that could operate on the battle front. GS shops in a more fixed location could use specialized equipment that was not easily moved to provide more complex maintenance capabilities. The specific tasks of the DS and GS shops were not easily distinguished. But during wartime, DS shops generally provided more direct exchange (DX)[7] service and direct assistance to combat units than did GS shops. To do this, DS shops maintained maintenance float items[8] and repaired or reclaimed damaged items explicitly to return these items to their primary users. GS shops assisted the DS shops in providing these services but concentrated more on repairing damaged items for return to the supply system, on calibrating maintenance equipment and helicopter components, and on manufacturing critical unavailable items. These tasks removed GS shops one step from combat units because they required a longer turnaround than the DS shops' tasks. The execution of these tasks also benefited from the specialized equipment that a fixed location allowed and the

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[6]Conversion of a helicopter typically involved a large enough change to warrant changing the helicopter's designation. Modification was less drastic; it was the depot's response to a Modification Work Order (MWO), which the Army issued in response to specific problems in any particular model in the fleet. Both required manufacturing capabilities that could be justified only at a central location.

[7]A supply concept in which combat units received new or reconditioned parts on a one-for-one basis for damaged parts turned in for repair.

[8]"Float" was a stock of items kept on hand to replace items immediately when they were turned in for repair. It was the inventory required to keep a specified percentage of issued items operational.

specialized skills and equipment that the broader-based workload of a GS shop justified.

During peacetime, DS and GS maintenance were performed both in military units that would go into the field in wartime and in installation shops that employed only civilians. Theoretically, military DS and GS units were supposed to perform the same types of tasks in peacetime or wartime; installation shops were supposed to complement these units with both DS and GS maintenance. In practice, civilian shops often provided the DX service that DS units will provide in wartime and did appear to fill in the gaps in maintenance not covered by local military units. Civilian shops also provided back-up support for the activities military units did undertake.

Organizational maintenance occurred within the combat unit itself. It emphasized preventive maintenance, including routine inspection, cleaning, lubrication, and simple replacement of parts. DS units assisted and advised combat units in these tasks and occasionally inspected organizational maintenance procedures for a higher command. One crew chief was typically assigned to each helicopter to assure that helicopter's organizational maintenance. A shortage of crew chiefs in the late 1970s forced the Army to give them responsibility for more than one helicopter each.

This standard Army four-category system—depot, general support, direct support, and organizational—was used to maintain most Army helicopters in CONUS. The Army would continue to use it for avionics maintenance, but all other maintenance would shift to a new three-category concept.

Three-Category Maintenance

Integrated direct-support maintenance (IDSM) evolved out of Vietnam experience. In Vietnam, DS maintenance companies detached units of mechanics called contact teams to aviation companies. This increased the quality of maintenance service by allowing many DS tasks to be performed at the helicopter airfield. In addition, several GS tasks were shifted back to the depot, leaving residual DS and GS tasks that could be performed in an integrated "intermediate" maintenance company. The experiment worked well.[9]

IDSM integrated responsibility for 60 percent of the traditional DS tasks with organizational tasks within the aviation companies themselves. (See Fig. B.1.) The maintenance performed within aviation

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[9]For more details and additional rationales for the change, see FM 55-45 final draft (December 1976), pp. 2-2 to 2-4.

companies was called aviation unit maintenance (AVUM). Remaining DS tasks were integrated with 40 percent of the GS tasks and performed in aviation intermediate maintenance (AVIM) companies. The remaining 60 percent of GS tasks were transferred to the depot.[10] This change, already completed in Europe and under way in the 101st Airborne Division in CONUS during the late 1970s, would bring Army aviation maintenance more into line with the three-level systems in the other services.[11]

ARMY ORGANIZATIONS INVOLVED IN HELICOPTER MAINTENANCE

The Army did not have one organization concerned with the operation and maintenance of helicopters. It was structured around military units, each of which used and integrated several weapon systems. This made it different from the other services, which generally organized units around major weapon systems.[12] It also resulted in a fairly complex organizational structure. Here we briefly review the role of the policy offices and major commands that affected the maintenance of helicopters in CONUS.[13]

Policy Organizations

The offices of the Assistant Secretaries of the Army for Installation and Logistics and for Manpower and Reserve Affairs provided civilian leadership for Army maintenance, but most operational policy issues

[10] Paul L. Lewis, Army Logistics Center, personal communication, 13 April 1979.

[11] While IDSM was being conceived and tested, the Aviation Requirements for Combat Structure of the Army, in its third round (ARCSA III), recommended a number of additional reforms that have affected Army maintenance of helicopters. Two important reforms had been approved by the late 1970s. One concentrated on helicopters to take advantage of scale economies in logistics and applied the IDSM concept fully only where sufficient concentration of helicopters existed. The other shifted control of a division's AVIM company from the Division Support Command (DISCOM) to the division aviation battalion.

[12] A widely used phrase in the Army said that "the Army equips men and the Navy and Air Force man equipment." This difference in philosophy led to a difference in organization.

[13] A number of organizational overviews of Army maintenance are available. Two particularly useful ones are the U.S. Army Command and General Staff College's *The CONUS Support Base* (1976), and the *Supply Management Reference Book (1976)*, maintained for the Army by its Logistics Management Center. The U.S. Army Logistics Management Center *Program of Instruction for Army Maintenance Management Course* (1976) provides an excellent bibliography of regulations and other relevant Army documents. This appendix draws on these and other sources to provide an organizational description specifically relevant to Army aircraft maintenance.

were raised and resolved within the General Staff. Three offices within the General Staff had primary responsibility for setting helicopter maintenance policy. (See Fig. B.2.)

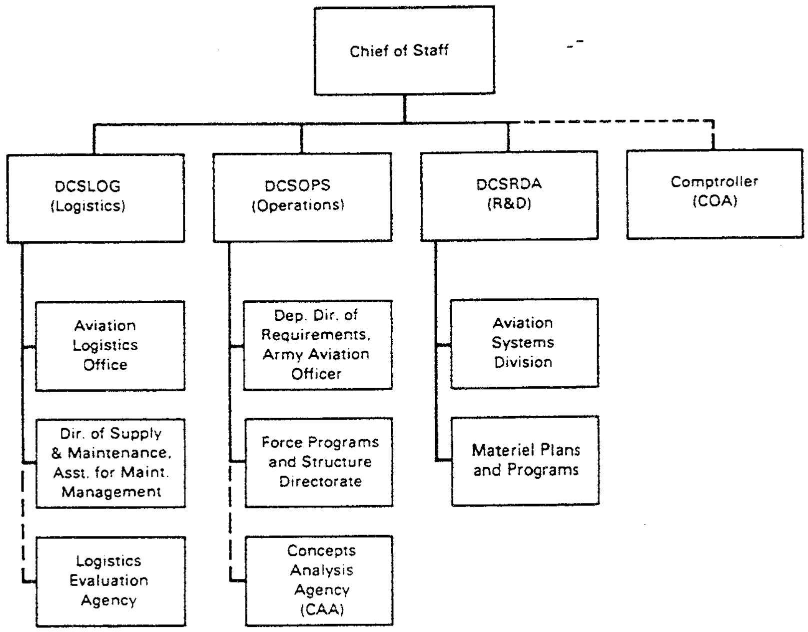

Fig. B.2—General staff responsibility for helicopter maintenance

Deputy Chief of Staff for Logistics (DCSLOG). The head of the DCSLOG Aviation Logistics Office was Mr. Joseph P. Cribbins. He had become an institution within DCSLOG. He acted as a focal point for any policy issues related to helicopter logistics including maintenance policy. Other parts of DCSLOG were responsible for coordinating general maintenance concepts and policy. The most important of these was probably the Office of the Assistant Director of Supply and Maintenance for Maintenance Management, which was responsible for general policy planning and programming and for the incorporation of maintenance engineering concepts into Army maintenance doctrine.[14] It was assisted in these tasks by the Army Logistics

[14]Examples of such concepts included integrated logistics support (ILS), the idea of

Evaluation Agency (LEA). This agency provided longer-term analytic support than DCSLOG could maintain in-house and acted as a tasking center for analytic support from other parts of the Army. It was also the logistics proponent in the Army's life cycle costing programs for new systems. As a whole, DCSLOG was the single part of the General Staff with the greatest responsibility for helicopter maintenance. Its policies and the schedule for their realization in operational objectives were published annually in DAPAM 701-1. This provided a reasonably good snapshot of policy changes likely to affect helicopter maintenance at any given time.

Deputy Chief of Staff for Operations (DCSOPS). The Deputy Director of the DCSOPS Requirements Directorate was double-hatted as DCSOPS Army Aviation Officer. He was responsible for the Army's flying hour program—its plan for the use of helicopters in peacetime or wartime—and the military requirements for manpower and equipment associated with this program. The DCSOPS Force Programs and Structure Directorate, through its responsibility for developing force structure and following unit authorizations, also affected helicopter maintenance. And DCSOPS could call on the Concepts Analysis Agency (CAA) for long-term analytic support in examining force structure and general doctrine. Both affected helicopter maintenance.

Deputy Chief of Staff for Research, Development, and Acquisition (DCSRDA). The chief of the DCSRDA Aviation Systems Division was responsible for procurement of aircraft. His office affected maintenance through its policy responsibility for the design of new aircraft and for approving product improvement proposals. Approved product improvement was executed by the Army helicopter depot system. The DCSRDA Directorate of Materiel Plans and Programs also affected procurement policy for helicopter maintenance.

Other Offices. Other parts of the General Staff also affected maintenance policy. For example, the Comptroller of the Army (COA) Directorate of Cost Analysis maintained an Aircraft Team within its Materiel Programs Division to examine the costs of new helicopter technologies and of alternative force structures. But primary policy responsibility resided in these first three offices.

Major Commands

Detailed planning and actual execution of helicopter maintenance occurred in the major commands. Three were of great importance to

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considering alternative maintenance strategies in the planning of a weapon system; and the Standard Army Maintenance System (SAMS), a comprehensive maintenance information system planned to increase the visibility of maintenance in lower categories. SAMS is discussed in more detail in Sec. III of the text and Appendix C.

helicopter maintenance in CONUS. The Materiel Development and Readiness Command (DARCOM) coordinated the technical development of new helicopters and of the manpower and equipment requirements associated with the operation and maintenance of these new helicopters. It also provided the wholesale or depot maintenance system for existing helicopters. The Training and Doctrine Command (TRADOC) developed concepts and doctrine for the use of new helicopters. It brought these concepts and doctrine into practice by developing the manpower and equipment requirements for helicopter maintenance units, and by determining what maintenance skills the Army required and what training was required to create these skills. And it provided all formal individual training in maintenance skills in the Army. The Army Forces Command (FORSCOM) commanded combat units stationed in CONUS and the installations at which they were stationed.[15] It was primarily responsible for assuring the readiness of helicopters and maintenance shops in these units and for providing these units with unit training.

DARCOM. The office in HQ DARCOM that affected maintenance most directly was that of the Materiel Management Directorate's Associate Director for Maintenance. The office acted primarily as a focus for programs that affected more than one readiness command. Examples were oil analysis and reliability-centered maintenance. Most of the analytical capability in this office had shifted to individual "readiness" commands within DARCOM.[16] The other office of importance to maintenance was the Readiness Directorate, which followed force readiness, DARCOM's provision of customer assistance through Logistic Assistance Offices, the progress of integrated logistics support, and product improvement programs. Again, this office acted more as a focus for coordination than as a decisionmaking point.

Below headquarters, four subordinate commands and a number of smaller offices in DARCOM affected helicopter maintenance. (See Fig. B.3.) The Aviation Research and Development Command (AVRADCOM)[17] supervised the development of new aircraft and of their requirements for manpower and equipment. It also maintained and exercised cost models designed to predict the operating and

[15]FORSCOM had counterparts in Europe and Korea that also provided installation and in-the-field maintenance, but we are concentrating on maintenance in CONUS.

[16]As part of a reorganization which is still ongoing, the Army Materiel Command (AMC) changed its name to the Army Materiel Development and Readiness Command. That reorganization, through recent personnel cuts in DARCOM, has effectively shifted most decisionmaking capability to the subordinate readiness commands within DARCOM. Deane (1975), Kirwan (1976a, 1976b).

[17]This was formerly part of the Aviation Systems Command in the old AMC.

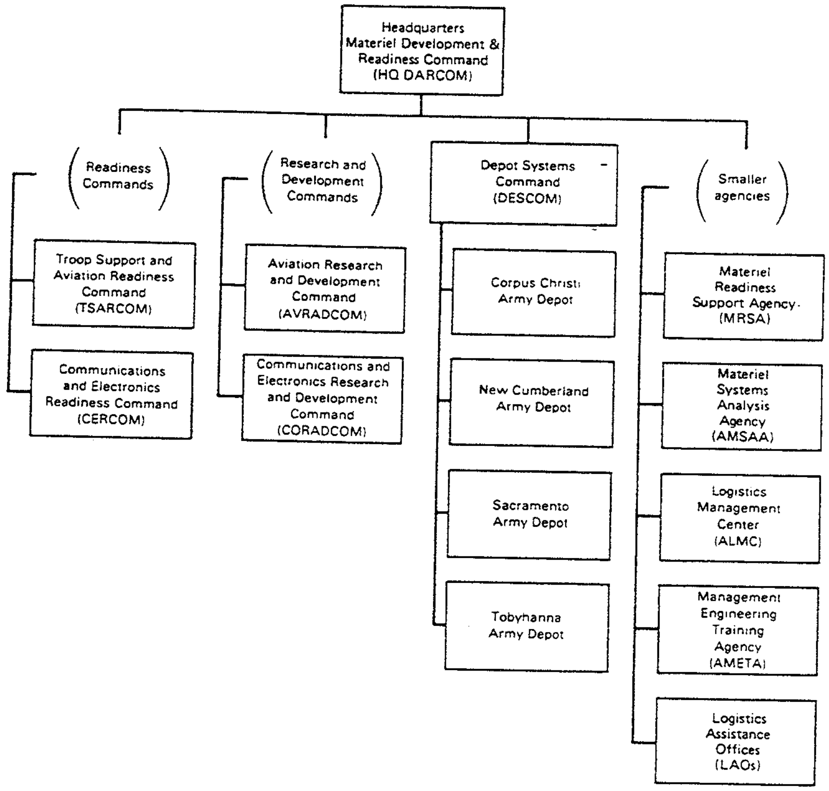

Fig. B.3—DARCOM responsibility for helicopter maintenance

support costs of new systems. The Troop Support and Aviation Materiel Readiness Command (TSARCOM)[18] was responsible for maintenance and supply of existing helicopters. It did not actually run maintenance depots, but it played an active role in their operation through its national maintenance point. This office managed scheduling, workload determination, technical assistance, and reporting. TSARCOM also served as a focal point for ongoing Army helicopter maintenance at all levels and maintained several information systems to fulfill this responsibility.

[18]This contained elements of the former Troop Support Command (TROSCOM) and AVSCOM, combined to take advantage of their collocation to cut overhead costs.

AVRADCOM and TSARCOM were primarily responsible for parts of a helicopter other than avionics.[19] The Communication Electronics Materiel Readiness Command (CERCOM)[20] supervised the maintenance of avionics components through a national maintenance point like that in TSARCOM. Research and development responsibilities were handled by the Communications Research and Development Command (CORADCOM).

Finally, DARCOM's responsibility for wholesale maintenance was actually executed through the Depot System Command (DESCOM), which served as an administrative headquarters and focus for Army depots. DESCOM assigned the maintenance workload generated by readiness commands to specific depots and coordinated programming and funding of maintenance performed. DESCOM's workload assignment function was somewhat attenuated in helicopter maintenance. Only two depots maintained helicopter airframes and nonavionics components: Corpus Christi Army Depot and New Cumberland Army Depot. Because each of these handled different aircraft and components, DESCOM had no discretion in where to send particular helicopter maintenance jobs.[21] DESCOM could workload avionics into either Sacramento Army Depot, the "primary" depot for avionics, or Tobyhanna Army Depot, giving it somewhat more discretion here.[22]

In addition to the direct line functions provided by these subordinate commands, DARCOM provided a number of other services affecting helicopter maintenance. The Army Materiel Readiness Support Agency (MRSA) maintained the basic data files that TRADOC used to write manpower authorization criteria (MACRIT). It served as an information link between the system and maintenance engineers in TSARCOM and CERCOM and the schools in TRADOC that documented manpower requirements. It also received the Army Maintenance Management System (TAMMS) reports from operating units and forwarded them to TSARCOM. TAMMS was the single most important maintenance information system in the Army; MRSA played

[19]Weapon systems ancillary to helicopters, such as guns and missiles and their fire control systems, were handled by readiness commands that specialized in such weapons. The most important were the Armaments Materiel Readiness Command (ARMCOM) and Missile Materiel Readiness Command (MIRCOM). They had parallel research and development commands.

[20]Under AMC, this was part of the Electronics Command (ECOM).

[21]For example, all CH-47 airframes were maintained at New Cumberland. Corpus Christi handled most other jobs performed in-house. DOD regulations required that 30 percent of depot maintenance be contracted out. TSARCOM and CERCOM controlled this decision on specific maintenance jobs.

[22]A primary Army depot was workloaded to capacity before any work of a particular kind was sent to secondary depots. In effect, secondary depots provided backup capacity for a particular type of job in the Army.

a much smaller role in the use of aviation data collected through TAMMS than it did in the use of data on other systems.

Another important information system within DARCOM was managed through the Logistics Assistance Offices (LAOs) that DARCOM maintained at major Installations throughout CONUS. These served as homes for field maintenance technicians (FMTs) from the individual readiness commands in DARCOM. FMTs provided local assistance and were an information link between materiel users in the field and materiel servicers in the readiness commands and HQ DARCOM.

The Army Materiel Systems Analysis Agency (AMSAA) gave DARCOM an in-house analysis capability. AMSAA generally undertook longer-term studies of basic logistics concepts such as the correct formulation of manpower authorization criteria or the likely demand that combat damage would generate for spare helicopter components.

The Army Logistics Management Center (ALMC) was one of the few Army schools outside TRADOC. It taught maintenance and other logistics managers—primarily civilians—courses on basic planning, management, and analytic skills as well as institutional knowledge required to run Army logistics. It also served as a home for logistics analysts who produced Army manuals, pursued basic research, provided consulting services, and maintained the Defense Logistics Studies Information Exchange (DLSIE), a computerized logistics bibliography.

Finally, the Army Management Engineering Training Agency (AMETA) trained management engineers for all the services and maintained a management engineering research and consulting capability. Among several Army publications produced here were the staffing guides used as yardsticks in setting civilian manpower requirements in many parts of the Army, including maintenance.

TRADOC. TRADOC achieved its role in military maintenance training and doctrine primarily through the schools it supervised; the Logistics Center (LOGC), a coordinating center for the Quartermaster, Missile-Munitions, Ordnance, and Transportation Schools; and the Combined Arms Center (CAC), a coordinating center for the Armor, Aviation, Infantry and other combat arms schools. Logistics and nonlogistics schools played a part in this process. (See Fig. B.4.)

Combat arms schools determined the form of organizations within which helicopters were used and given organizational maintenance. The most important of these were the Infantry (Ft. Benning), Armor (Ft. Knox), and of course the Aviation (Ft. Rucker) Schools. The Transportation School (Ft. Eustis) determined the form of military direct-support and general-support aviation maintenance units. The Ordnance School (Aberdeen Proving Ground) provided plans for mili-

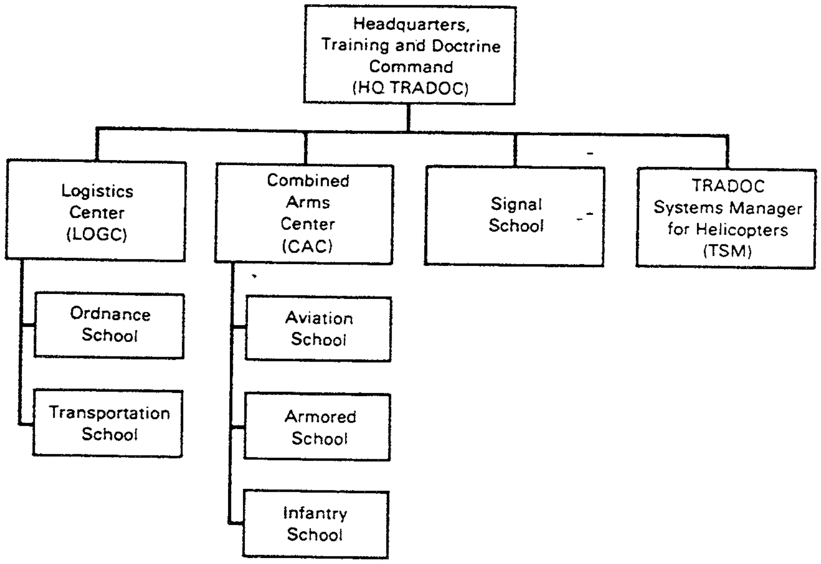

Fig. B.4—TRADOC responsibility for helicopter maintenance

tary general-support units that might support, among other systems, aircraft.

In addition to determining the form of military units in which helicopters were maintained, TRADOC also documented what skills are required to develop these skills. Another set of schools performed this set of functions. A school responsible for defining and developing a given military skill or military occupational specialty (MOS) also typically provided the individual training for this skill. The Aviation School developed and trained helicopter pilots and crew chiefs, the mechanics responsible for organizational maintenance on any given aircraft. The Transportation School developed and trained all other military nonavionics mechanics. The Signal School (Ft. Gordon) developed and trained military avionics mechanics in the late 1970s; the Transportation School was attempting to consolidate this maintenance skill with the others it supervised at the time.

It is obviously impossible to structure organizations without understanding the skills of the personnel in them or to determine the skills necessary to an organization without knowing how it will use them. As a result, the organization-oriented offices in these schools reviewed

the training documents that other offices and schools wrote for the skills their organizations would use. Training-oriented offices and schools similarly reviewed organization-oriented documents.

The Logistics Center played a role in this coordination effort, but its function usually involved coordination of documents and concepts that affected more than one logistics function—for example, maintenance and supply or maintenance and transportation. It also served as a simple administrative link between HQ TRADOC and its four schools. TRADOC had most recently attacked the coordination problem for helicopter systems by creating a TRADOC system manager (TSM) for helicopters. This was ultimately meant to provide the same focal point for aviation problems within TRADOC that helicopter systems program managers did within DARCOM. But the office was still too small and too new to determine how important a role it would play.

FORSCOM. FORSCOM supervised the use and maintenance of all Army helicopters in combat units within CONUS. Maintenance was performed in fixed location installation shops with civilian mechanics and in-the-field shops stationed at these installations but employing military mechanics. Military and civilian shops coordinated their activities rather closely. An installation that supervised a civilian shop had the same commanding general as the division stationed at that installation, and the installation and division shared comptroller and other important management services. Nonetheless, FORSCOM's role was somewhat different for its military and civilian shops.

As noted above, TRADOC developed the form of military maintenance organizations. FORSCOM played an important advisory role in creating new organizations and revising old ones, but it deferred to TRADOC for final approval and documentation. FORSCOM, then, effectively took these forms as given and performed military maintenance within them. The division was the primary unit of management. (See Fig. B.5.) Two Corps Headquarters existed and provided some administrative links between the divisions in these corps and HQ FORSCOM. But they were more important as coordinating centers for nondivisional combat units within the corps. Each active division was designed to have one military direct-support aviation maintenance company attached to the division's aviation battalion.[23] In addition, FORSCOM maintained six active military

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[23]The 101st Airborne Division (Airmobile) uses more helicopters than other divisions and is organized somewhat differently. Many direct-support functions are integrated into the aviation companies in the 101st Aviation Group in an integrated direct-support configuration. What is not integrated is performed by two direct-support maintenance companies, in the division's aviation maintenance battalion. The battalion also includes a general-support aviation maintenance company attached to the division, another peculiarity.

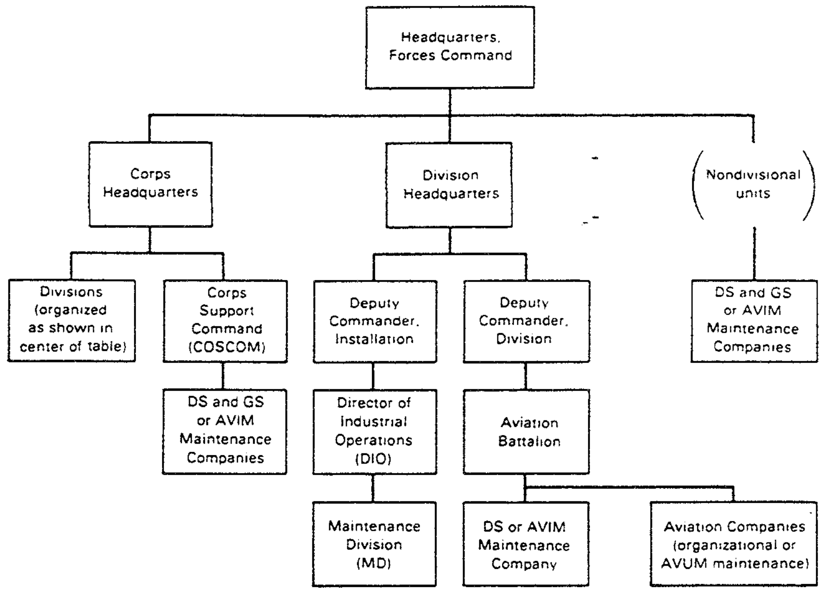

Fig. B.5—FORSCOM responsibility for helicopter maintenance

general-support aviation maintenance companies, usually among nondivisional forces.[24] With the move to three-category maintenance, these were to be replaced by four active AVIM companies in CONUS. All of these shops used only military labor, reported through a military chain of command, and were funded through military channels. TRADOC prescribed the form of direct-support companies, and FORSCOM attempted to keep these units as similar to one another as possible. TRADOC and FORSCOM treated general-support companies the same way.

FORSCOM had much greater responsibility for its installation shops. It determined their form and the skills and equipment needed in them. And it managed them. Maintenance shops were located within the Maintenance Division of the Directorate of Industrial Operations (DIO) on an installation. Staffing guides from AMETA in

[24]Again, the 101st Airborne is an exception.

DARCOM provided broad guidelines for defining the form of these organizations, but their actual form varied considerably from one installation to another. An installation maintenance shop usually provided general-support and some direct-support maintenance for all equipment in the collocated division and for nondivisional units in its vicinity. The form of the shop was defined by the workload it could expect in providing this service. HQ FORSCOM had ultimate responsibility for approving the organization of installation maintenance but there was much local control.

SUMMARY

Several offices under the Secretary of the Army provided civilian leadership to helicopter maintenance, but most operational decisions were made at a lower level in the late 1970s. Within the General Staff, DCSLOG, DCSOPS, DCSRDA, and the Comptroller contributed to the formation of maintenance policy. The DCSLOG Aviation Logistics Office was a focal point for all aviation maintenance policy decisions within the General Staff.

More detailed planning and management occurred within the major commands below the General Staff. DARCOM had direct administrative control of wholesale aircraft maintenance in CONUS. FORSCOM administered installation and in-the-field intermediate and organizational aircraft maintenance in CONUS. TRADOC played an important planning role in in-the-field maintenance by defining the form of organizations and types of skills to be used there. It also provided individual formal training for in-the-field maintenance mechanics. In addition to its administrative responsibilities, DARCOM supervised the development of new maintenance concepts and new helicopter technologies and maintained technical expertise on existing helicopters. Together DARCOM and TRADOC formulated, documented, and introduced new maintenance concepts and helicopter technologies. And FORSCOM used them.

Appendix C

GENERAL INFORMATION FLOWS IN ARMY AVIATION MAINTENANCE

The information relevant to resource allocation flowed through the activities in Army aviation maintenance in five basic ways: formal continuous systems, formal periodic systems, local information and analysis offices, joint working groups, and informal communication.[1]

FORMAL CONTINUOUS SYSTEMS

TAMMS

The Army Maintenance Management System was the primary data source for actual maintenance experience in the Army. Among other things, TAMMS supported manpower requirements determination with data on annual maintenance manhours, requirements determination for inventories of spare parts, and baseline calculations of reliability, availability, and maintainability in the development of new aircraft. Through these uses and others, TAMMS affected the requirements processes in Army aviation maintenance at their most fundamental level. Its importance to resource allocation cannot be stressed enough.

TAMMS was based on a log book that maintained a historical record of the receipt, operation, condition, maintenance requirements, modification, and transfer of each individual aircraft.[2] Selected data were extracted from these log books on a regular basis, reduced to machine-readable form, and forwarded to MRSA, which sent these directly to TSARCOM for compilation into regular reports to HQDA and the major commands on fleet status and various maintenance topics. These reports were used primarily above the installation and division level. TAMMS was in a period of transition in the late 1970s.

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[1]This appendix deals only with information flows within the Army. For an overview of relevant information flows from the Army to OSD, flows that carry data discussed in this section to OSD, see Giesler et al. (1976).

[2]Because it was an Army-wide system, TAMMS included log books for all other major weapons as well. The information kept differed from one weapon system to another. TSARCOM and CERCOM are responsible for determining exactly what information would be collected on aircraft and avionics components.

Itself a variation of the old Army Equipment Reporting System (TAERS), TAMMS was scheduled to be replaced in the 1980s by a more advanced system, the Standard Army Maintenance System (SAMS).[3]

Production Control Systems

Each Army maintenance shop and unit had a production control system of some kind. The most common systems were the Combat Service Support System (CS_3), used by military DS shops;[4] the Support Maintenance Management System (SMMS), used by civilian installation shops; and the Standard Depot System (Speedex), used in depots. Other systems were being tried in selected locations, but all of these systems provided the same type of information. For example, all included data on number, type, and status of jobs performed. These often included data on manhours used. All included information on backlogs. Installation and in-the-field systems maintained the log books and property books used to produce TAMMS data. They were also more concerned with readiness of assets and availability of authorized equipment than depot systems were. The depot and installations systems gave more attention to cost, budgetary, and productivity data than the in-the-field systems did. But the primary emphasis at the installation remained more on manhours and parts consumption than on costs per se. All the standard systems suffered from a failure to integrate directly with related supply information systems like the Standard Army Intermediate Logistics Systems (SAILS). At least one experimental system had achieved such integration,[5] and integration was considered an important component in SAMS and future versions of SMMS.

These information systems allowed local managers to maintain control over maintenance. They also served as a basis for reports to higher headquarters. TAMMS reports were an example. Others included monthly reports to HQ FORSCOM on backlog, manhour costs by work center, and productivity. HQ FORSCOM also got quarterly reports on end items repaired and costs. The depots sent DESCOM

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[3]SAMS was being promoted as much more than simply a replacement for TAMMS. It was to be integral part of the Standard Army Logistics System (SALS), an "orderly, cohesive plan to coordinate and direct all segments of the Army Logistics System . . . [that] enables issuance of coordinated tasking directives," U.S. Army Command and General Staff College, 1976, p. 1-4. See also Hammer (1975). Our treatment of SAMS considers only those aspects of it designed to replace TAMMS.

[4]We also found this being called the Command Maintenance System in the field.

[5]Corps Automated Maintenance Management System (CAMMS), used at Fort Bragg, North Carolina.

biweekly program status reports on work center performance and quarterly reports on productivity.

Though not formally a production control system, the Commitment Accounting and Management of Unit Supplies (CAMUS) system was a related control system of special interest to aviation maintenance. It was used in conjunction with a financial system,[6] to determine the cost of spare parts consumed by aviation maintenance companies. It was the primary source of data on spare parts for the calculation of flying-hour rates.

Readiness Reporting Systems

Two systems monitored the readiness of Army aviation assets. One, the Operational Readiness Management System, was used only for aviation.[7] TSARCOM used it to collect information on all Army aircraft inventories, assignment, location, and operational readiness status. Readiness goals were set for each type of aircraft, and performance was judged relative to these goals.[8] Readiness was measured by the number of hours ready during a month divided by the total number of hours in a month. It was measured both for individual aircraft and for total aircraft of a given type in an aviation unit.

Units self-reported their readiness levels each month to TSARCOM. TSARCOM used these reports to prepare summary reports for DA DCSLOG and DCSOPS and for other staff agencies. The most important report was "Army Aircraft Inventory Status and Flying Time," also known as the "Goldbook." FORSCOM units also reduced the raw data sent to TSARCOM to machine-readable form and transmitted these to HQ FORSCOM. HQ FORSCOM compiled a report similar to the TSARCOM Goldbook for internal uses within FORSCOM and for the Chief of Army Reserves (OCAR).

The second reporting system, authorized by AR 220-1,[9] applied not just to aviation, but to all Army systems. It provided the basic measure of performance most important to military unit commanders, by determining whether a unit was rated in Readiness Category I.

The system covered both human and physical assets. Two types of physical assets were identified. "Pacing items" were the primary

[6]The Standard Army Financial System (STANFINS).

[7]AR 95-33, "Army Aircraft Inventory Status and Flying Time," 22 September 1976.

[8]Utility and observation helicopters, depending on specific model, had goals of 70 to 80 percent readiness. Heavy-lift helicopters had goals of 65 to 70 percent; attack helicopters had 70 percent as a goal.

[9]"Unit Readiness Reporting," August 1978.

weapon systems in a military unit; in an aviation company, they were the company's helicopters. These were distinguished from all other items. To be rated in Category I in a particular month, each pacing item and an unweighted average of all other items had to be ready at least 90 percent of the time during the month.[10] A helicopter was considered 100 percent ready under this system if it met the standard set for it in AR 95-33, 65-80 percent *actual* readiness, depending on the model. Hence, the unit reporting system was somewhat more lenient than the Operational Readiness Management System.[11] DARCOM tied into data from this system with the Army Logistics Readiness Evaluation System (ALRES).[12] ALRES obtained monthly readiness data from HQDA DCSOPS, isolated trends in them relevant to equipment readiness, and followed these up through its Logistics Assistance Offices.

LAOs and FMTs

DARCOM maintained Logistics Assistance Offices (LAOs) at some major FORSCOM installations. They served as the interface between HQ DARCOM and the logistics community including materiel "users," "developers," "suppliers," and readiness commands. The materiel readiness commands located field maintenance technicians (FMTs) within the geographic area of responsibility of the DARCOM LAOs. Their primary duty was to assist local maintenance shops in resolving equipment, technical, and maintenance management problems. They also reported equipment failures and performance to the materiel readiness commands. For example, TSARCOM's FMTs tracked operational readiness and problems likely to affect the whole fleet of helicopters. They also kept track of unusual events and expedited quality deficiency requests on an ad hoc basis.[13] Their familiarity with local circumstances was enhanced when they gave local maintenance shops hands-on technical assistance and OJT. Such assistance also appeared

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[10]That is, let P_{ij} be the number of hours the ith helicopter of the jth model is ready in a month. Let O_{ij} be the number of hours the ith item of the jth reportable type, other than helicopters, is ready. Let M be the number of hours in the month. Then a unit attains Category I if $\sum_i P_{ij}/M > .9$ for all j *and* $\sum_i \sum_j O_{ij}/M > .9$.

[11]This potential leniency was somewhat offset within FORSCOM by a major command decision to adjust required readiness levels upward several percentage points for aircraft in late 1978.

[12]DARCOM Pamphlet P 700-16 (May 1978).

[13]QDRs were a variation on and replacement for the equipment improvement request (EIR). EIRs were effectively suggestions from local aviation and maintenance units on how to improve the performance of aircraft through technical changes in them.

to improve rapport between FORSCOM mechanics and DARCOM FMTs. The importance of these activities varied with location.[14]

FORMAL PERIODIC SYSTEMS

Inspections and Audits

Inspections and audits appear to have been similar activities in Army aviation maintenance. Both were typically reviews of a maintenance activity's conformance with regulations and official guidelines. We will not attempt to differentiate between them here except to note that inspections were sometimes unscheduled and appear to have been more important to military units; audits were always scheduled and were more important to civilian shops.

Military aviation and aviation maintenance units were subject to many inspections through the year; three of these appear to have been the most important. The Aviation Resource Management Survey (ARMS) was the principal external aircraft inspection that a FORSCOM aviation maintenance unit had to stand. It was also the most comprehensive, covering everything from safety to maintenance and quartermaster procedures. An inspection team of up to 25 people was scheduled for a week at each division, scaled to the number of aircraft in the division. It was conducted in tandem with the safety inspection from the Aviation Safety Board at Fort Rucker (USAAVS).

The Command Maintenance Evaluation Team (COMET) inspection, sponsored by the division Inspector General (IG), was generally the toughest local inspection a military maintenance unit experienced. It was aimed at all types of units and hence could not give as much attention to aviation maintenance as the ARMS inspection did; in fact, in some divisions, the COMET did not inspect aviation maintenance at all. Where it did not, the Inspector General's annual inspection took its place. Where it did, however, it came unannounced and, because it was a local inspection, allowed thorough follow-up on any failures.

The third inspection of importance to military units, the Early Deployment Readiness Evaluation (EDRE), was also unannounced.[15] It involved a staged field exercise in which a military unit's tactical capability was tested. Although the EDRE was aimed most directly at

[14]Materiel readiness commands also placed field supply technicians in LAOs where supply problems were particularly difficult. Their role was similar to that of the FMTs.

[15]Although they are unannounced, units know as a practical matter that their inspections come at least six months apart. Hence, they have a grace period following each inspection. The EDRE adequately measures performance only for the period outside this grace period.

the combat aviation components of a division, maintenance was also tested in its ability to field aircraft for the exercise and maintain them during the exercise.

Inspections affected civilian maintenance shops significantly only at the installation. FORSCOM's installation shops were included in the annual Inspector General inspection. A number of other inspections occurred for both civilian and military maintenance shops, but the local shops did not consider them to be as important. For example, very few personnel in the field were familiar with the Command Logistics Review Team, a group of specialists from HQDA, DARCOM, and elsewhere, which conducted a comprehensive review of local maintenance activities. The team billed itself more as an assistance than as a monitoring group.

Audits came from all levels. The General Accounting Office of the Congress, the Defense Audit Agency of OSD, and the Army Audit Agency (AAA) in HQDA monitored aviation maintenance on an ad hoc basis. An Internal Review (IR) office responsible to HQDA was attached to the comptroller at each FORSCOM installation to coordinate and follow up these audits. The results of AAA audits ("Statements of Conditions and Recommendations" or SOCARs) were also circulated through a regular Army publication.[16] Audits varied in content. They most typically dealt with an installation's compliance with regulations and guidance from higher headquarters but also dealt with broader management issues on occasion.[17]

Each of the major commands also used audits as one form of control. The most important ones to resource allocation were the equipment survey teams. DARCOM used a Command and Equipment Management Program Review (CEMPR) team to reconcile property books with the TDA and justify a depot's equipment. FORSCOM used an Equipment Survey Team (EST) to do the same thing.[18] The Inspector General double-checked compliance with AIMI and ACIMS programs[19] in FORSCOM through periodic local IR audits. And although an installation IR office was directly responsible to HQDA, the installation commander could generally call on a third or more of its resources to conduct local audits as required.

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[16]This was DA Circular 36-1. AAA audits were of special importance to maintenance because more than half of all AAA audits focused on logistics issues. Gleason (1971), p. 29. See also DA PAM 37-4 (1976), pp. 63-64.

[17]Cf. Bennewitz (1971).

[18]ESTs serve the additional purpose of transmitting information on innovation through FORSCOM as it travels.

[19]The Aircraft Component Intensive Management System (ACIMS) and Aviation Intensively Managed Items (AIMI) system are related programs to restrict local hoarding of high value components.

Management and Engineering Survey Teams

Three types of teams were important. The first was primarily used by DARCOM. DARCOM maintained a methods and standards (M&S) team to advise depots on the use of industrial engineering methods and monitor their implementation.[20] DESCOM fielded an Industrial Engineering Team (IET) to assist depots with technical and procurement problems and with modernization planning. This team was fielded in 1975 to deal with some specific problems and its future was not clear in the late 1970s. It differed from the other activities we examined in that it carried information to the maintenance shops instead of carrying it away to supervisory headquarters.[21]

Both FORSCOM and DARCOM used a second form of survey team, the Manpower Survey Team (MST). MSTs played a much broader role than the auditing function performed by their apparent analogs, the Equipment Survey Teams. MSTs played a central role in the formation of TDAs for depots and installation maintenance shops. The dominance of "local appraisal" freed them from the guidelines set forth in official Staffing Guides and delegated much of the major command's responsibility for manpower requirements determination to them. Where conflicts arose over requirements, the MSTs served as a liaison between the major command headquarters and the local maintenance activity. One would expect the industrial engineering skills embodied in the first type of survey team to be important here. But MST members typically had formal training in neither industrial engineering nor cost-benefit analysis.

DARCOM fielded the third type of survey team, but its primary effect was on FORSCOM units. TSARCOM sent the Aircraft Condition Evaluation (ACE) team to each FORSCOM unit with helicopters once a year to determine which aircraft would be overhauled in the next year. On the basis of airframe inspections, the ACE team assigned each aircraft a Profile Index (PI). Aircraft with PIs higher than a set level were then candidates for overhaul. Although ACE teams did conduct detailed inspections, these inspections were not used to evaluate local commanders. They were simply a means of informing TSARCOM of the condition of aircraft, for whose materiel readiness

[20]Methods and standards was the name given in the Army to an OSD-initiated program, the Defense Integrated Management Engineering System (DIMES). Personnel in the field continued to use the old name, DIMES, in the late 1970s.

[21]FORSCOM also encouraged the use of M&S and other industrial engineering techniques, but it did not use survey teams to do so. Instead, the Management Analysis Division of each installation comptroller (where this division was present) acted as the local proponent for M&S. Unfortunately, a lack of command emphasis and hence of funding effectively impaired the effectiveness of local M&S programs. FORSCOM was centralizing M&S functions at HQ FORSCOM during the late 1970s.

TSARCOM itself was ultimately responsible (Shelhorn, 1974; Tuggey, 1977).

Requests for New Investment

Decisions about what facilities and equipment a maintenance activity would use were quite centralized. When a local commander wanted new capital items, he could look forward to a lengthy approval process. Which process he used depended on the type and size of the request. Facilities over $75,000 were MCA-funded; other facilities came from OMA funds. Equipment in civilian shops and depots less than $1,000 also came from OMA funds. All their other equipment came from OPA or OMA funds. DARCOM's SB 700-20 listed, by item number, which should be used.[22]

Each year, the Director of Maintenance proposed facility additions he wanted for his directorate to the installation MCA committee. He provided a detailed justification for each proposal. Although an economic analysis was required in this justification, it is often omitted (GAO (1977a)). The committee ranked the proposals it received and submitted the list, with justifications, to HQ FORSCOM, which integrated this list with those from other divisions, preserving each list's ordinal ranking. It submitted the integrated list to HQDA for review and integration with requests from other major commands. Similar integration continued all the way to Congress, where a decision was made on total MCA funding.

Facility requests in a depot proceeded similarly. Only the chain of command was different. Requests were compiled at the depot, then at DESCOM, at HQ DARCOM, and at HQDA, where they were integrated with requests from FORSCOM for further consideration.

The ranking process was accompanied by formal justifications for each request and by informal bargaining, bartering, and lobbying at every level. Each of these consumed real resources at a maintenance manager's disposal, including resources directly under his control and good will he had accrued with superiors and others who could influence the process. In the end, then, the maintenance manager could pay a heavy price for these "free" facilities (cf. Lindblom, 1955; McKean, 1965). He also had to wait out the term of the approval cycle, reducing the value of inputs obtained in this way in relation to the value of resources he could obtain more quickly.

To buy new equipment costing more than $1,000, a local com-

[22]The Army was apparently considering a less complicated split between the two, perhaps allocating responsibility for all procurement to one or the other.

mander had to get separate approvals for authorizations and funding. Depots sent requests for TDA approval, with a justification, to DESCOM. This process was formalized in the Depot Maintenance Plant Equipment (DMPE) program. The real decision was made here, but a final TDA authorization was not issued until finalized by the DARCOM Installation Support Activity. Although located at Rock Island, Illinois, this was HQ DARCOM's representative. Installations sent requests, with justifications, directly to HQ FORSCOM. For DA controlled items (so identified in SB 700-20), HQDA approval was also required.

At the same time, funding authorization is requested. When TDA authorization was obtained, the relevant command (DESCOM or FORSCOM) approved a Procurement Order Number (PRON) for each item approved. This authorized the commitment of OPA or OMA funds, depending on the type of equipment. Within DARCOM, the relevant readiness command transferred OPA funds to the Defense Industrial Production Equipment Center to obtain OPA-funded equipment. Individual depots used their own funds to procure OMA-funded items. A similar division of responsibility applied within FORSCOM.

Other obstacles were also built into the procurement process. For example, a TDA authorization was not adequate for procurement approval for standard Army equipment until the equipment in question was authorized on the "master" TDA file. Because this was updated only biannually, a manager could expect a delay in effective TDA authorization of three months and could experience delays of six months. Then if TDA and PRON approval were not obtained in the same fiscal year, the request process had to be repeated the following year. And even when full approval was obtained, procurement had to proceed in accordance with the Defense Acquisition Regulations (DAR). Among other things, these reduced the manager's ability to buy the specific type of equipment he wanted. The DAR could be avoided for OPA-funded equipment in DARCOM if the Defense Industrial Plant Equipment Center (DIPEC) already had the equipment needed in stock. (The readiness commands could transfer equipment not currently needed to DIPEC and receive a credit for it in return. DIPEC could then dispose of it or hold it for a future DOD user.) Of course, this restricted the manager's choice also, and when he obtained OMA-funded items with his own funds all of these transactions costs were added on top of the monetary price he paid.

LOCAL INFORMATION AND ANALYSIS OFFICES

Information and analysis activities existed throughout Army aviation maintenance.[23] Two different types of activities can be distinguished. The first was best at dealing with technical problems. In civilian shops, this capability was likely to reside in the industrial or maintenance engineering activity of the maintenance division. At the installation, it might reside above the Maintenance Division within the Directorate of Industrial Operations. In this situation, it might be of only limited usefulness to maintenance. Such capability was not formally incorporated into military units. They had to rely on whatever capability resided in the collocated installation or on the field maintenance technicians of the installation Logistics Assistance Office. No matter where industrial and maintenance engineering was conducted in Army aviation maintenance, it was more likely to be done by experienced mechanics than by academically trained engineers. These mechanics generally looked down on the engineer's lack of knowledge of an actual shop operation. Their thoroughly pragmatic approach to technical problems reflected this view.

The second type of analysis activity was more concerned with managerial problems and budgeting or what the Army called resource management. In the depots, the Review and Analysis Section in the Comptroller conducted this analysis. At the FORSCOM installation it was usually the Management Analysis Division of the Comptroller or its equivalent.[24] A military division's reliance on the collocated installation's comptroller for resource management extended to management analysis. The Maintenance Analysis and Instruction Teams (MAITs) could potentially provide some military capability, but were not always well informed about aircraft maintenance.[25] In general, the Management Analysis Division was the local office with the greatest responsibility for considering management alternatives conducted by the local comptroller. Management analysis elsewhere in the Comptroller was less concerned with weighing alternatives

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[23]For an overview, see DAPAM 37-4 (1976), pp. 54-66.

[24]As noted earlier, the post Internal Review Office occasionally addressed management problems, but usually dealt only with audits.

[25]MAITs found themselves in the awkward position of not being able to report failings they observed to assure that they were corrected, while being mistrusted by many military units afraid that the MAIT would report on them. This mistrust was a holdover from the recent past when the MAIT was in fact an inspection team. MAIT members with memories of that period could aggravate this misunderstanding by attempting to regain their former authority. Where this happened, the effectiveness of this potentially useful assistance activity was neutralized.

than with analyzing the budget per se, predicting budgetary needs, interfacing with the POM[26] process, and so on.

JOINT ADVISORY AND WORKING GROUPS

Because two different major commands developed manpower and materiel for aviation maintenance and others actually produced that maintenance, problems with resource allocation naturally cut across several of them. When these problems become serious enough, the Army set up senior or study advisory groups (SAGs) and other joint working groups to deal with them. These groups included representatives from the "developers" (TRADOC and DARCOM) and "users" (FORSCOM and other major troop commands) relevant to the problem. Among the user representatives might be the mechanics who actually performed the maintenance. But deference to rank weighted such groups in favor of higher ranking (supervisory) individuals and limited the effectiveness of lower ranking members included in the group. The groups were rarely able to conduct their own studies because members were called in from other full-time duties. But they could task studies from the major analysis activities in the Army (for example, AMSAA, CAA, LEA, LOGC, and ALMC) and elsewhere. Decisions were reached by consensus. Because ranking officers held greater weight in any consensus, the final decisions often reflected a considerable amount of experience; the past played an important part in the solutions to current problems.

As one might expect, such working groups were costly and were formed to deal only with the most pressing problems. The resources devoted to any working group and the breadth of skills included would reflect the importance of the issue. For example, such major issues as the choice of a new aircraft type or the implementation of Reliability Centered Maintenance received high command emphasis. Less important issues such as the decision to distribute a Modification Working Order or the formation of a new TOE required the same breadth of communication but were handled less formally, often through routine, established lines of communication. Each major command had a major advisory role in support of the other major commands. Proposals for change were routinely circulated within and between them for feedback, and the lines of communication created by this circulation allowed the resolution of many intercommand problems. Formal advisory groups appeared when this informal network had failed to resolve a problem or when it was not advisable to assign

[26]Program Objective Memorandum, a budgeting document.

any one major command the proponency for resolving an issue. Problems of this kind were major problems that could justify the cost of a SAG or its equivalent.

INFORMAL COMMUNICATION

Army bulletins and publications, trade journals and fairs, and similar media helped bring information on opportunities into local maintenance activities. Trade journals and fairs and direct commercial solicitation appeared to play the dominant role in telling civilian maintenance managers what capital items were available and desirable. But the most important form of informal communication was more personal. Networks of contacts spanned major commands and subordinate commands within them at all levels. The networks had easily defined boundaries and associations that appeared to have little relationship to formal organization charts and mandated communication.

For example, the development of the MACRIT and its use in TOE development involved people in all the major commands. MRSA maintained the data used in TRADOC schools to write the MACRIT; TSARCOM updated these data with data collected by FORSCOM units; HQDA DCSPER finalized and published the MACRIT; TRADOC used it, together with other "feeder" data from TSARCOM and AVRADCOM and with feedback from HQ FORSCOM, to design TOEs; when HQDA DCSOPS had finalized a TOE, the process of forming MTOEs started. Myriad interconnections affected these simple tasks. Four things characterize the networks these interconnections formed. First, they were not conscious of themselves. Each individual in a network knew the other individuals with whom he had to deal to do his job, but he was unlikely to know any people in the network with whom he did not deal directly.[27] Second, even individuals who dealt with one another routinely were not well informed about the content of their counterparts' jobs. They knew what information they expected from another person and what was expected from them, but they had little understanding of how the information was obtained and manipulated or how it would be used when it left them. Third, in spite of this apparent segmentation, these networks were long-lived. Such a task as maintaining the MACRIT, for example, had been performed by the same network of individuals

[27]Exceptions existed, of course, but they were not located in predictable places. In particular, individuals with some overview of a network were not always in a supervisory position looking down on the network as a whole.

for many years. The fourth characteristic is implied by the third: Most members of these networks were civilians. Where an office with a military commander lay within a network, the civilian deputy (the "institutional memory") was the identifiable link in the network, not the commander.[28]

In sum, information routinely moved through informal, well-established, finite networks of which no one in the Army had a good overview. The establishment of a SAG tended to illuminate these networks somewhat by bringing together many of the members who had never dealt with one another directly or at least by mobilizing them all in a nonroutine effort. In fact, a major contribution of a SAG appeared to be the illumination of these informal paths and the identification of gaps in them. Paradoxically, SAG recommendations along these organizational lines were unlikely to have any effect unless these informal networks were broken up and reoriented. Because they had formed spontaneously over time to deal with inadequacies in formal communication systems, the dissolution of formal arrangements was unlikely to affect them. This was almost certain to be true if recommendations failed to take account of past difficulties and advanced new formal arrangements that would fail without the continuing support of informal connections. But even if new formal arrangements were well designed, individuals might not perceive the benefits of these arrangements as being sufficient to change their behavior and learn new routines—major changes represented a precipitous depreciation of their human capital that they might not wish to accept (Arrow, 1974, p. 56). Such job-oriented motivations were compounded by personal attachments that grew between individuals in any network. The conservatism inherent in these persistent bonds could easily undo attempts at reform. The least visible source of information was likely to be most tenacious.

SUMMARY

The aviation maintenance shops in the Army were linked together and to other Army activity with a variety of information systems. The TAMMS was the keystone of the Army's maintenance information

[28]That is not to say that informal networks of military individuals were not important. An insular occupation like the military is more likely than most to promote such networks, and we observed numerous occasions where information on resource options passed between "old friends." But the short tours of military personnel prevented these informal contacts from developing into task-oriented networks, networks that support the MACRIT; TOE or MTOE writing; development of SAMS, RCMS, LSAR and life cycle costing; and so on.

system. This was supplemented by several different production control systems and by reports from field maintenance technicians. The TAMMS and LAO reports were used primarily at higher levels of authority; data from production control systems were used both locally and to produce summary reports for higher commands. These continuous maintenance-oriented systems were supplemented by two readiness reporting systems.

Periodic monitoring systems were used primarily to ensure that the self-reported data in the continuous systems were consistent with actual performance. Military units were subject to several inspections each year. These included both scheduled and unscheduled exercises. Civilian units were more likely to experience scheduled audits. These audits gave special attention to the inventories and other capital assets held at a local activity but they covered a broad range of issues and originated everywhere from the GAO down to the local command. Inspection teams and auditors were supplemented by survey teams that facilitated the use of industrial engineering tools and determined the condition of individual aircraft.

Although the Army devoted considerable resources to collecting information in central locations, it remained a fairly decentralized organization. The dispersion of information and analysis activities through Army aviation maintenance confirmed this. Local maintenance activities generally had access to technically oriented and to management and budget-oriented information activities. When interdependence dominated a particular problem, however, the Army asserted a modicum of central control and established joint working groups. These groups made decisions by consensus and hence lacked the decisive nature that a true centralized system would exhibit. They were also uncommon, being reserved only for acute problems. For the vast majority of problems, the Army relied on its formal monitoring systems and on the informal networks that emerged to knit the organization together. The vitality of these informal systems made change difficult unless it explicitly addressed their reorganization.

Appendix D

WRITING REQUIREMENTS AND AUTHORIZATIONS DOCUMENTS FOR MILITARY ORGANIZATIONS

Tables of Organization and Equipment and Modification Tables of Organization and Equipment were the fundamental documents used in the late 1970s to define the combinations of capital and labor that military maintenance units used in the field. Their comprehensive nature required that they involve every major command in their formulation and many individual activities as well.

Theoretically, a TOE defined the requirements for all units of a particular kind,[1] and an MTOE tailored the authorizations for any specific unit of a particular kind to its specific needs. TRADOC wrote TOEs; each major command wrote the MTOEs for its own units. Using the concept that TOEs and MTOEs were supposed to reflect wartime needs and that those needs were likely to be more or less the same for all units of the same kind, FORSCOM had adopted a policy of attempting to write the same MTOEs for all units of the same kind under its control.[2] It considered several hundred requests for variances each year and allowed many of these, but they were minor; MTOEs were essentially the same for all FORSCOM units with the same TOE. Once set, MTOEs served as the primary document that FORSCOM units could use to request equipment and personnel. They received all the equipment authorized by the MTOE and an allocation of manpower lower than their authorization. This final allocation of equipment and manpower determined the capital-labor mix in a military unit.[3]

[1]Three examples are TOEs 55-407H1: Transportation Aircraft Maintenance Company, Transportation Aircraft Maintenance Battalion, Airmobile Division; 55-459H5: Transportation Aircraft Maintenance Intermediate Support Company; and 55-570G: Aircraft Maintenance Team.

[2]Exceptions were made for climate control equipment likely to be needed in Alaska and the Canal Zone.

[3]TOEs and MTOEs did not include all the capital a unit was authorized. Uniforms, clothing, individual equipment, furniture, food service and laundry equipment, training ordnance, and medical and other expendables were authorized through Common Tables of Allowance (CTAs). Spare parts inventories were authorized through Authorized Stockage Lists (ASLs) and Prescribed Load Lists (PLLs). Manuals and the contents of tool kits were determined, for aviation maintenance units, by TSARCOM distribution systems and documents. But all other capital items—and this accounted for most of the capital value of a military maintenance unit—were authorized by the MTOE. Although

When an aviation maintenance TOE was to be written or revised, the TRADOC Logistics Center or Combined Arms Center assigned proponency to one of their schools.[4] The school began the assembly of three documents: the Basis of Issue Plan (BOIP), Quantitative, Qualitative Personnel Requirements Information (QQPRI), and the Manpower Authorization Criteria (MACRIT). The BOIP was an equipment-oriented document and was used when TOEs were being revised to accept new types of equipment. Among other things, it listed what types of units would receive the equipment, in what quantity, what it would replace, and what new equipment would be required to support it. It also included a detailed list of changes in personnel levels and skills that would be required to support the new equipment. This personnel list was based on the MACRIT and the QQPRI.

The MACRIT was a table of factors defining the number of people in each military occupational specialty required to support one aircraft in each category of maintenance. These factors were based on historical experience in Army aviation maintenance. When available, they were used as an input to the QQPRI. When no historical experience was available—for example, when a TOE change resulted from introduction of new equipment—human factor studies, logistic support analyses, and related methods were used to write the QQPRI. As experience accumulated, historical data were used to replace the hypothesized factors. When complete, the QQPRI specified the skills required to support equipment deployed in accordance with the BOIP. It also laid out the training required to produce these skills.

TRADOC schools were responsible for developing each of these documents, but they relied heavily on DARCOM for data to support each one. When a new piece of equipment was introduced to an aviation maintenance company, for example, AVRADCOM gave TRADOC BOIP "feeder data" and "qualitative" QQPRI data. These data were materiel-oriented as opposed to force-oriented. They provided detailed data on what was effectively a unit-equipment (UE) basis. For example, qualitative aspects of the QQPRI included data on item cost, annual maintenance manhours per item, and the MOS characteristics required to support an item. AVRADCOM developed BOIP and QQPRI data jointly. Where a prime contractor developed the equipment for AVRADCOM, he also developed these BOIP and QQPRI data as part of the formal life-cycle costing process.[5]

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the discussion is phrased in terms of the development of a new TOE, it is equally applicable to consideration of a change in an existing TOE. The same is true of the MTOE.

[4]See Appendix B for a discussion of TRADOC organization.

[5]These data were developed along with the MAC charts and all other basic data required to field a system. In effect, once the operational requirements of a new system

When equipment had been used in the past, TRADOC could draw MACRIT manpower factors from AR 570-2. If it was not satisfied with the existing MACRIT, however, it could recommend development of a new one. In practice, revision was extremely difficult. For example, the most recent revision of the aviation maintenance MACRIT followed the previous revision by 12 years. Even then, it was precipitated by the adoption of IDSM, a maintenance concept that left the previous MACRIT meaningless.[6]

A revision required permission of HQDA DCSPER. When that was obtained, the proponent TRADOC school requested the most recent direct productive annual maintenance manhours (DPAMMH) factors from DARCOM. TSARCOM used TAMMS data to develop these for aviation in the form of manhours per flying hour by type of aircraft, MOS, and category of maintenance. MRSA stored these data and, for most intermediate aviation maintenance uses, provided them to the Transportation School in TRADOC. The Transportation School converted them to MACRIT data by applying the following simple formula or a simple variation on it to each aircraft type, MOS, and category of maintenance:

$$\frac{\text{MACRIT}}{\text{factor}} = \frac{\text{Persons}}{\text{Aircraft}} = \frac{(1.4)\ (\text{DPAMMH})\ (\text{Annual flying hours/aircraft})}{\text{Annual available hours/person}}\ .$$

Multiplying by 1.4 added in indirect productive time, assumed by custom to be about 40 percent of direct productive time.[7] Annual flying hours/aircraft and annual productive hours/person were determined by TRADOC doctrine. Once a revision was completed, it was forwarded through channels to HQDA DCSPER who, upon approval, published it as a change to AR 570-2.

DARCOM, then, forwarded UE data, directly or indirectly, to TRADOC for further development of the BOIP and QQPRI in a force con-

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were set, the capital-labor mix associated with that system was in the contractor's hands. He determined the mix.

[6]Another example is the wheeled vehicle maintenance MACRIT, which, despite repeated efforts, had not been revised for over a decade. Regulations required revision at least every three years.

[7]For a justification of this adjustment, see *Manpower Authorization Criteria for Aircraft Maintenance and Technical Inspection Operations (MOS 67/68 Series),* ACM 12159, final draft, U.S. Army Transportation School, Fort Eustis, Virginia, May 1977, hereafter, *MACRIT Revision for Aircraft Maintenance.*

text. With advice from other TRADOC schools, the proponent school determined the density of issue, the specific changes in equipment and personnel required in a TOE, other TOEs likely to be affected by the change, and the specific training requirements implied by all these effects. When these documents were finalized, they contained all the data required to write a draft TOE. The school, known in this role as the combat developer, circulated the draft to the trainers, TRADOC schools that would have to support the recommended changes with training programs; the materiel developer—for aircraft, AVRADCOM; and the logistician, DCSLOG's Logistics Evaluation Agency (LEA). When consensus was reached here, the draft TOE was sent to HQDA for review and consent. Following consensus in DA, the school prepared a tentative TOE for field review. The troop commands, in our case FORSCOM, were given 30 days to review proposed TOEs. This did not allow time for feedback from the actual units likely to be affected. If HQ FORSCOM was satisfied, the TOE was finalized.[8] As with the TDA, as long as six months could pass before the new TOE was consolidated into the official data base FORSCOM had to use to implement it.

By comparison with TOE development, MTOE development was fairly simple. It was complicated only by FORSCOM's desire for uniformity. Typically, a FORSCOM unit initiated a request to change its MTOE.[9] This was forwarded through channels to HQ FORSCOM. If the change appeared relevant to all FORSCOM units of the same type, HQ FORSCOM could request a TOE change. This was then staffed by a TRADOC school, initiating the process we have just reviewed. Otherwise, HQ FORSCOM could approve the variation and request HQDA's approval. No further approval or consultation was required.

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[8]Although regulations called for this process to be repeated at least triennially for each TOE, it rarely was.

[9]A similar procedure would be followed in implementing a new MTOE; in that case, the initiative came from above rather than from below.

Appendix E

AVERAGE COST, MARGINAL COST, AND ADMINISTERED PRICES

Prices were used extensively within Army aviation maintenance, but they generally did not contain the type of information that would facilitate continuous adjustment of resource use to reflect changes in relative input costs over time. They were more often used to facilitate accounting control. This appendix examines some of the details of connections between costs and three forms of administered prices in Army aviation maintenance: industrially funded depot prices, spare parts and component prices, and flying hour rates.

INDUSTRIALLY FUNDED DEPOT PRICES

Table E.1 illustrates the formula used to calculate the manhour rate to be charged for depot work. It sums a series of components that together constitute an average cost of production. Even if each category were correctly calculated, this would not be correct. We are interested in the amount by which a particular job changes total cost.[1] If a customer—the readiness command in this case—were to make the choice for the Army between depot maintenance and some other option, it had to be able to weigh the full cost it imposed on the depot by accepting the depot's services against the full cost of other options. Any particular job was not likely to affect the cost of base operations or administration, certainly not by as much as its prorated share of total labor hours. These costs should not have been charged to the job.

How then do we recover them? To choose the best way to do this, we must know something about the production function of the depot.[2] Suppose the depot uses only fixed proportion processes and has no stochastic effects in its environment. Figure E.1(a) illustrates this case.[3] MC is the incremental or marginal cost of producing an additional unit of depot services. It is constant at P_0, from zero output

[1]This should be adjusted, of course, for the value of OJT associated with the job.

[2]This discussion of production characteristics draws on the literature of electricity pricing. Surveys which address many of the issues raised in a theoretical context include Anderson (1972) and McKay (1978).

[3]For a more complete development of this case, see Steiner (1957).

Table E.1

CALCULATION OF THE RATE CHARGED FOR A MAINTENANCE JOB

Direct labor rate + within shop costs + indirect expense of mission + indirect expense of base operations + general and administrative expenses = the rate

$$\text{Direct labor rate} = \frac{\text{Total D/L Costs (minus overtime)}}{\text{Planned D/L (worked) hours}}$$

$$\text{Within shop} = \frac{\text{Indirect Costs (within the mission production centers)}}{\text{Planned D/L (worked hours) in production cost centers}}$$

$$\text{Indirect expense of mission} = \frac{\text{Direct overhead cost from mission and Base operations directly identifiable to mission costs}}{\text{Planned D/L (worked hours) in production and production cost centers}}$$

$$\text{Indirect expense of base operations} = \frac{\text{Mission share of costs}}{\text{Planned D/L (worked) hours in production and production support cost centers}}$$

$$\text{General and administrative expenses} = \frac{\text{All costs}}{\text{All mission planned D/L (worked hours)}}$$

to the depot's capacity, $\bar{Q}$, at which point it becomes infinite.[4] Average cost, represented by AC, lies above it at any quantity less than $\bar{Q}$.[5] Changing depot output below its capacity, then, changes costs by P_0 per unit. But charging p_0 leaves full costs uncovered. For example, if MB is the marginal benefit of depot services to a readiness command, charging p_0 per unit leads to a demand for Q_0 units and leaves $(AC_0 - p_0)Q_0$ of fixed cost uncovered. Charging p_A induces a demand of Q_A and

[4]If $Q = \min(x_F/a_F, x_V/a_V)$ for x_F = quantity of fixed input and x_V = quantity of variable input, then the fixed input is set at $a_F\bar{Q}$, and the variable input varies from 0 to $a_V\bar{Q}$. The cost function is then $C = p_F a_F \bar{Q} + p_V a_V Q$, p_i = unit cost of the ith input. And marginal cost is $p_0 \equiv p_V a_V$, a constant.

[5]AC is a rectangular hyperbola constructed with respect to an origin at p_0. It recovers a fixed amount, $p_F a_F \bar{Q}$, at any $Q \leq \bar{Q}$.

covers all costs. Unfortunately, it makes depot services look more expensive than they really are. In particular, it forces the readiness command to make a decision that reduces net benefits by the shaded area.[6] This area can be retained in one of two ways.

First, charge the readiness commands only the variable cost of production and recover the fixed costs with a direct appropriation for the depots. This will induce the readiness commands to expand demand from Q_A to Q_0 and generate the net benefit to the Army forfeited by average cost pricing. This has one serious shortcoming. Fixed costs are incurred because of demand for depot services. Therefore, total benefits from the depot services should exceed these costs.[7] If the readiness commands do not bear these costs, someone else must determine whether benefits from depot services in fact cover costs. The readiness commands, who under this arrangement effectively get subsidized depot services, have an incentive to overstate the benefits they receive from the services. Their parochial view of their own importance will add to this exaggeration, particularly because they have no budget guidance from the Army, transmitting its view of their importance to them. In sum, the people most likely to know the benefits of depot services will provide biased information to the decisionmaker responsible for fixed depot costs.

Charging them an annual subscription fee for depot services is the second way to retain the shaded area of net benefits. The problem here is allocating the fixed cost to them. No particular allocation, in itself, is correct. The best one is the one that minimizes their movement away from Q_0 in Fig. E.1(a).[8] This is more likely, the less the cost allocation depends on actual consumption of depot services. To that extent, the responsiveness of the subscription fee to this service level should be greatest for readiness commands with the fewest options.[9]

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[6]The shaded area is the integral,

$$\int_{Q_A}^{Q_0} (MB - p_0)dQ,$$

of the difference between marginal benefits and costs.

[7]In economic parlance, fixed costs should not be larger than the consumer surplus of the readiness commands.

[8]More precisely, it is the one which minimizes the sum of shaded areas for all readiness commands. To the extent that consumption must move from Q_0, inducing the same percentage change for all readiness commands minimizes the shaded area. See Ramsey (1923), Baumol and Bradford (1970).

[9]This is simply the inverse-elasticity or Ramsey rule for pricing (Ramsey, 1923; Baumol and Bradford, 1970). It also suggests that the distinction between the fixed and variable components of price is not always clear. For example, a declining block price structure is one way to impose the subscription fee. In fact, if the exact annual workload can be negotiated ahead of time, no distinction is required; a single lump-sum fee will

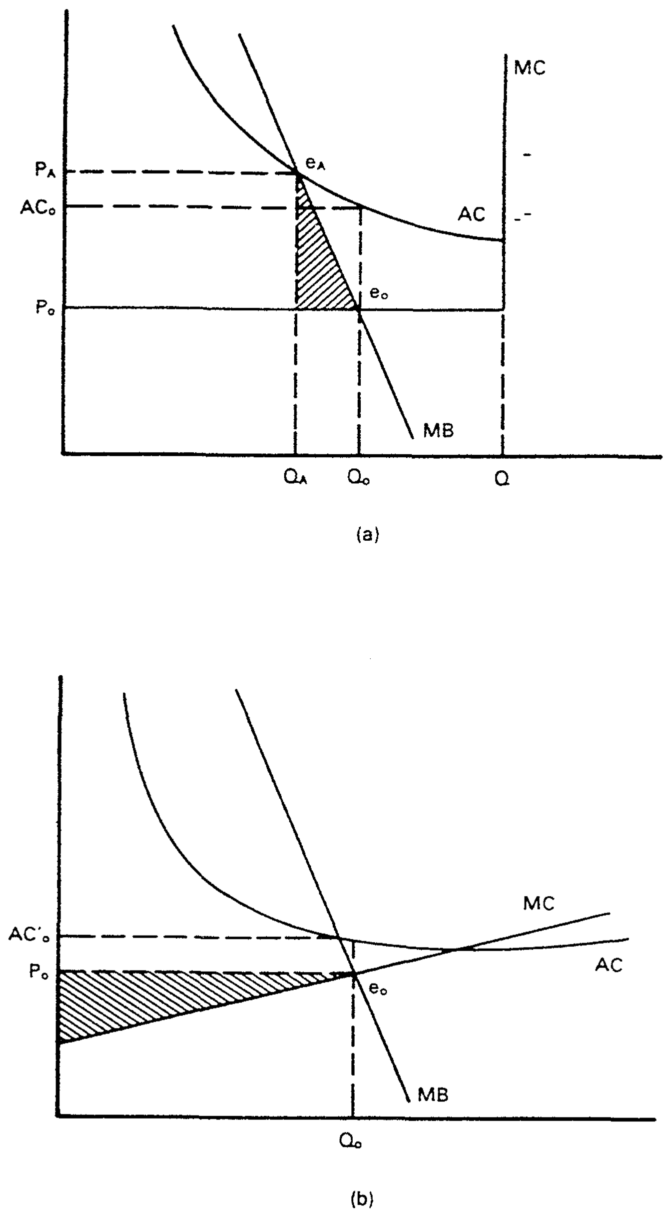

Fig. E.1—Effects of average and marginal cost pricing

All of these conclusions require that the depot use only fixed proportion processes. As Sec. III suggests, this is unrealistic. Considerable substitution is possible. In this case, the unit cost of production increases with the level of output.[10]

Figure E.1(b) illustrates this. Now a price reflecting incremental costs can take many values. If MC and MB intersect at e_0, as in Fig. E.1(b), the revenue the depot receives, p_0Q_0, will now cover part of the fixed costs of the depot. The shaded area in Fig. E.1(b) is available to cover fixed costs.[11] With given fixed costs, average costs are now lower at Q_0. They are potentially lower than the price based on marginal cost, suggesting that the depot may collect even more revenues than required to cover fixed costs with no separate fixed fee. In our example, the divergence of average and marginal cost has simply been reduced; this will always be true when marginal cost increases with output. The remainder of fixed costs should still be covered by a subscription fee. But increasing marginal costs reduce the difficulties of covering fixed costs.

The average cost pricing schedule in Table E.1 not only charged for fixed costs that should have been covered differently, it failed to capture the variability of unit costs. This is unimportant if production is steady at one level through the year; it is critical if production varies over the year.[12] In this case, our analysis suggests that price should also vary over the year. Changing the price over the year tells the readiness command that the cost it imposes on the depot varies over the year and encourages the readiness command to substitute away from periods of high cost (and high demand) to those of low cost (and demand). It encourages readiness commands to smooth their demands over the year.

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be sufficient. All that is requested is that the readiness commands be made aware of the marginal cost they will bear during the negotiations so that they can choose the appropriate level of workload. Keeping the fixed and variable components distinct beyond the negotiations stage is just a way to split the risks associated with an uncertain workload. If, as is often assumed of public agencies, the depots and readiness commands are risk neutral, risk does not impose a cost and no one form of splitting is more advantageous than another. If, however, these activities reflect the risk averseness of their managers, as is likely, an optimal splitting arrangement can be found and this should be reflected in the distinction between fixed and variable charges.

[10]Now $Q = f(x_F, x_V)$; $dC = p_V dx_V$, $dQ = (\partial f/\partial x_V)dx_V$, and $dC/dQ = p_V(\partial f/\partial x_V)^{-1}$. Cost minimization requires that $\partial f/\partial x_V$ fall as x_V and Q rise, meaning that dC/dQ will rise. See Panzar (1976) for a more complete development of this case.

[11]Variable costs are now the integral

$$\int_0^{Q_0} MC\, dQ$$

under the marginal cost curve. The shaded area is the difference between revenues and this cost.

[12]For evidence of variability in Air force depot workloads and a discussion of its implications, see Kennedy and Howard (1973).

To the extent that variability in demand remains in the face of such pricing, the connection between average- and marginal-cost-based prices becomes more tenuous. Shaded areas like that in Fig. E.1(b) now differ in size by period (say, week or month) over the year. The fixed costs must still be recovered from the sum of these shaded areas and subscription fees. But the sum of shaded areas associated with a given level of total annual output will now depend on the time pattern of production over the year. It increases with variability.[13] Cost formulas like those in Table E.1 give little guidance about how to apportion fixed and variable components of price to cover costs.

They give even less guidance if the cost categories themselves do not adequately reflect actual costs within them. At least two problems exist here. First, estimated costs were based on self-reported historical experience in the late 1970s. As Sec. III suggests, self-reported experience overstated the use of labor and spare parts, leading to higher costs than necessary. Although this may have accurately predicted the funds spent in the coming year for a given workload, it did not reflect the funds actually needed. Slack used to pursue goals of little value to the Army could be cut out of these categories with better management tools. Second, depreciation of equipment and facilities was included in cost only in selected circumstances (usually when the depot sold a service to a non-Army or non-DOD user). When the depots are in steady state, yearly capital purchasing will approximate a valid measure of depreciation. When demand for depot services is falling over time, yearly capital purchasing severely understates real depreciation. First, equipment is not being replaced at the same rate as it depreciates, leading to one divergence. Second, equipment is falling in value faster than it would in a steady state, adding a second divergence.[14] Because many fixed costs covered by the shaded area in Fig. E.1(b) involve depreciation, any attempts to cover fixed costs properly are further aggravated.

In sum, the pricing system used for industrially funded depots did not convey cost information to the readiness commands that could be used to trade off depot services across time or against nondepot alternatives. The price reflected average costs. These could not convey good information on marginal costs. In particular, they provided no information on variations in marginal cost over the year. One result

[13]Consider a situation in which the same level of production occurs every week. Then decrease production in one period and increase it by the same amount in another. Because the shaded areas are basically quadratic functions of output (output is a linear measure; contribution to fixed cost is a two-dimensional area each of whose dimensions is monotonic in output), the decrease reduces contribution to fixed costs less than the same increase in output increases the contribution; a larger net contribution results.

[14]This affected only specialized equipment without a resale market outside the military. But a large portion of facilities and equipment fell into this category.

of this was that fixed costs could not be recovered in a desirable way. All of these problems were aggravated by the poor quality of information used to generate the average cost estimates.[15]

SPARE PARTS AND COMPONENT PRICING

When a unit received a new spare part or component, it either had to pay for it from its OMA funds or exchange a damaged item of the same kind for it.[16] Spare parts and components were available from a number of sources. New items accompanying new helicopters or a Modification Work Order (MWO)[17] on an aircraft were procured by the readiness command with procurement funds and provided free of charge to maintenance shops.

Other new items, mostly consumables, had to be paid for. Maintenance units and shops paid a standardized price for such parts out of their OMA funds. But the price was low; DODD 7420.1 required that "the expense of procurement, warehousing, repacking and handling, or any other function of supply administration pertaining to a stock fund item will not be financed from the stock fund or included in the standard price of the item . . . unless specifically authorized in a stock fund charter."[18] The price might include the current market price and certain transportation costs and expected costs of net losses in inventory.[19] These transportation and inventory costs were reflected

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[15]AR 37-55, which defined the cost accounting system used in Army depots, was being revised to reflect the latest OSD guidance in the late 1970s. It would continue to reflect average costs because this perspective was not limited to the Army alone. OSD had been attempting to obtain standardized depot cost accounts that would allow cost comparisons across the services for at least 15 years and had failed. This new revision was the latest episode in this ongoing effort. It is unfortunate that such considerable effort was being put into measuring numbers of such limited usefulness. The sunk costs of this effort could exasperate any attempt to collect better numbers; however, a new approach might help break the deadlock. See Tuggey (1977).

[16]Exchange items were limited to those for which expected repair costs were not high compared with their procurement cost. For example, to be eligible for inclusion in the Direct Exchange (DX) program, an item's average cost of repair could not exceed 65 percent of its procurement cost. This was one of several criteria set out in AR 710-2. The DX program supplied military units with recoverable, fast-moving items. Typically, demand came from DS units; GS units and installation shops exchanged good items for damaged ones on a one-for-one basis and, on receipt, repaired the damaged items for future exchange back to the DS units.

[17]An MWO was an authorization, with instructions, to alter an aircraft (or other major end item). Modification could occur at the depot or installation. Each MWO was accompanied by a kit with all the parts, specialized tools, and instructions required to make the modification.

[18]DODD 74200.1 (26 January 1967), VIII.A.6.

[19]DODD 7420.1 (26 January 1967), VIII.A.4. See AR-37-III for details of the Army implementation of this directive.

in an 11 percent surcharge on the procurement cost of stock fund items managed by TSARCOM.[20] Expenses other than the purchase price of the item itself, called distribution or wholesaling and retailing costs in the private sector, could account for half of the final cost of an item or more. Recent studies within DOD suggest shares as high as 90 percent in some cases.[21] The notion that DOD saved money by buying in bulk and avoiding wholesale and retail markups was misplaced, but it was hard to discuss when DOD's internal distribution costs were not identified as such. The Army was no exception.

It could be argued that these distribution costs are primarily fixed costs and hence not chargeable to an individual item. Private firms must charge for them to stay in business; in the government, a marginal cost-based price might be very close to the procurement cost. We know, however, that interest costs, many administrative transactions costs, and direct transportation, storage, and handling costs are directly chargeable. Large congestion costs in storage, handling, and information handling are also likely to lead to diseconomies which will offset some scale economies associated with overhead costs. Although fixed costs may justify some direct appropriations, then, not all distribution costs are fixed. And even for those that are, recall that proper control of inventories is enhanced by passing all costs to the inventory manager. With data available in the late 1970s, none of these issues was easily addressed. In any case, a maintenance unit bore only a portion of the real cost of consumable spare parts. The portion was likely to be higher on parts with high turnover, but current costing systems did not allow easy verification of this.

The Direct Exchange (DX) program was another source of spare parts and components. When military units exchanged damaged items for new with their installation shop, they were charged the average cost of repairing that item at the installation over the last six months. This cost included a direct labor charge, a charge for consumable spare parts used, and an allocation of overhead. We have already seen the inadequacy of the spare parts charge, and the same marginal

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[20]Readiness commands determined appropriate surcharges annually, subject to HQ DARCOM and HQDA review, as part of the budget review of the Army Stock Fund. TSARCOM had used an 11 percent surcharge for at least five years; other commands used surcharges of 9 to 12 percent.

[21]Interest costs were 10 percent a year by themselves. The Army did not revise its inventory rules to reflect this higher cost when the discount rate was changed from the rate on government bonds to its current level. Because pricing policies in the Stock Fund were more budget than resource oriented, the Stock Fund was not required to yield a return on capital. It needed only to maintain its nominal value of capitalization.

cost problems encountered in discussing the industrial funds apply here.[22]

FLYING HOUR RATES

Each year, the DCSLOG Aviation Logistics Office supervised the synthesis of data on flying hour costs into prices for Army helicopters. Different prices were charged to different users.[23] These prices were based on an intriguing mix of average and marginal costs. Table E.2 illustrates this.

The price in Row (3) is the rate, discussed earlier, used to determine flying hour budgets. The system of rates in Table E.2 implicitly recognizes that this was an incomplete statement of cost. When one Army unit or activity used another Army unit's helicopters, for example, it had to transfer not only sufficient funds to cover spare parts and POL costs, but also additional funds to cover any civilian maintenance required. Row (4) shows the average civilian labor required if only civilian labor was used; if only a fraction of maintenance involved civilian maintenance, only that fraction of this component was charged. Per diem costs of the owner unit's crew were also assessed if necessary. Row (6) represents the maximum rate that could be charged to another Army activity.

Such pricing passed on information on the costs an activity imposed on a helicopter's "owner" when that activity used the helicopter. As we found with the budgetary requirements rates, an activity owning helicopters could potentially retain any savings created by more efficient maintenance of aircraft "leased" by other Army activities. However, Army owners of aircraft could not use price competition to call attention to their efficiency, and a potential user of these aircraft could not recognize the cost savings available to the Army if he used an efficient owner's aircraft instead of someone else's, perhaps his own. Changes in the cost of providing helicopter services over time could not be transmitted to encourage use during periods when cost—and presumably workload—was low. This information had to be provided informally through barter or other means.

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[22]A revealing relationship to examine would be that between the GS and installation shop. Either could repair DX items. Both paid the same price for spare parts. The overhead allocation and direct labor charge should have provided a measure of the GS shop's shadow price for labor. Presumably, that would change over the year with variation in workload and be reflected by variations in exchange between the shops. However, any such analysis is likely to be confounded by the administrative nature of the prices and the availability of other bartering tools.

[23]These prices were administered by the Air Force, the DOD proponent for flight services. But they were based on cost studies by TSARCOM and COA and finalized by the Army Aviation Logistics Office.

Table E.2

ARMY STANDARD FY78 FLYING HOUR COSTS AND RATES[a]

Cost Components and Rates	Dollars per flying hour									
	AH-1G	AH-1S	CH-47A	CH-47B	CH-47C	CH-54A	CH-54B	OH-6A	OH-58A	UH-1H
(1) Cost of field OMA ports	155	215	318	318	318	336	336	38	38	59
(2) Cost of POL	49	51	148	158	198	180	170	9	11	45
(3) Price for budgeting requirements ((1) and (2))	204	266	466	476	516	516	506	47	49	104
(4) Cost of civilian labor[b]	75	95	97	95	88	116	116	20	19	28
(5) Cost of crew per diem[c]	15	15	29	29	29	29	29	15	15	22
(6) Price for intra-Army use ((3) + (4) + (5))	294	376	592	600	633	661	651	82	83	154
(7) Cost of ADA replenishment spares and depot overhaul costs	51	93	345	345	345	441	441	20	24	38
(8) Price for comparison of Army and commercial flight ((6) + (7))	345	469	937	945	978	1102	1092	102	107	192
(9) Price for non-Army, DoD use	419	550	1164	1172	1205	1430	1420	126	132	257
(10) Price for non-DoD use	709	901	2036	2046	2081	2349	2338	294	301	508

SOURCE: HQDA Message RUEADWD/2009, June 1978.

[a]Based on Army-wide average costs for airframe, avionics, and armaments.

[b]Assumes 100 percent civilian labor; if some military labor is used, only the civilian portion is charged for.

[c]Applied only if crew accompanies aircraft.

Row (8) displays the cost of Army aircraft that was to be used in choosing between the Army and commercial aircraft. This raises all the problems associated with an administered fleet-wide average cost and the potential for varying marginal costs raised with respect to Row (6). It raises similar questions about the price paid for commercial air services. The price of commercial air services could be taken at face value as the only commercial cost of importance to the Army. Here, the Army weighed the budgetary cost of a cash outlay against all the real costs it incurred for producing an equivalent amount of air services.[24] This reflects a narrow, Army point of view. Alternatively, the Army could weigh the real cost to society of taking private air services against the real cost of providing them internally. The market generally conveys real costs through the prices used in transactions. Scale economies, however, may lead to an allocation of overhead costs to individual transactions and an overstatement of real costs in the price the Army faces. Determining the importance of this overstatement of costs is probably difficult enough to warrant taking the commercial price at face value.[25] But this raises questions about the rate the Army used to reflect its own costs.

Where, for example, were the cost of military personnel and the variable components of utility costs and other facilities costs directly chargeable to aircraft maintenance? Where were the use-dependent depreciation of tools and equipment? And where were the distribution costs associated with spare parts and POL? Omitting these obviously understates the cost of military provision of services. Inclusion of some of the costs in Row (7) appears unwarranted, however. Presumably Row (1) covers all spare parts procurement costs, eliminating any need for further spares costs. And depot overhaul costs were dubious unless use of an aircraft could be shown to contribute to the need for overhaul. Until the mid 1970s, overhauls were performed under hard time limits, every 2000 flying hours. Under this system, use for one hour could be said to contribute 1/2000 of the cost of an overhaul.[26] In

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[24]To be equivalent, Army flying hours would have to be credited with the value of OJT jointly produced with the flying hours.

[25]The empirical evidence available suggests that production in the declining portion of a firm's average cost function—where price is likely to exceed marginal costs—is not common. Hence, the price the Army paid for commercial air services probably reflected actual marginal cost quite accurately. Careful empirical examination, an examination likely to be controversial and not likely to be conclusive enough to satisfy any legal standard of evidence, would be required to verify this.

[26]In purely technical terms, overhaul costs are joint costs that cannot be allocated over individual flying hours in a unique way. Economic welfare theory (for example, Baumol and Bradford, 1970) suggests that the best way to allocate such costs, if they must be allocated, is in a way that least distorts the use of helicopter services resulting if no charges were made. An average cost concept of charging 1/2000 of the cost per hour is one way to do this; a peaking cost approach is another. Establishing dominance of one over the other would require better data than we have now.

the late 1970s, however, overhauls were conducted under a condition monitoring concept; a helicopter was overhauled only when an Aircraft Condition Evaluation (ACE) team determined that overhaul was warranted. The deterministic relationship between use and overhaul no longer existed; a depot charge should reflect only the current extent of this relationship.

Whether the overcharges outweighed the undercharges is hard to determine, but it is not important to our argument. The accounting system designed to determine the proper rates for comparing Army and commercial alternatives appears to have been ill-conceived and likely to yield a proper number for comparison only by accident. This argument gains even more force when we consider that the real costs of each of these components change over time and the accounting system should be designed to track these changes.

The basis for moving from Row (8) to Rows (9) and (10) in Table E.2 is less clear. The move from (9) to (10) is more significant than that from (8) to (9); it presumably includes depreciation of the original aircraft. It is important to differentiate time-dependent and use-dependent depreciation here. Mechanical and especially electronic systems deteriorate over time whether they are used or not. Physical deterioration results from a system's increasing inability to perform in accordance with all its specifications. Technological deterioration results from improvements in enemy capabilities and technological advances that move forward the desirable date for replacing an aircraft. These time-dependent forms of depreciation occur whether a helicopter is released to be used on a specific occasion or not. Allowing someone to use an aircraft does not impose these forms of cost. Use-oriented depreciation, however, is a cost imposed on an aircraft's owner as a result of use, but this is presumably covered by the replacement of spare parts and by overhauls. Overhauls in particular are said to return an aircraft to new condition, thereby wiping out any use-oriented depreciation experienced by an aircraft.[27] In sum, aspects of depreciation relevant to a user charge are already covered in Row (8) and above. Further work could shed more light on the basis for the rates in Rows (9) and (10).

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[27]We found considerable controversy on this point in the field. Some planners and mechanics argued that older aircraft had higher maintenance costs. Because aircraft of different ages were not uniformly distributed through the Army or even FORSCOM, they worried that fleet-wide average costs discriminated against units with older aircraft. Other planners and mechanics believed that an aircraft is fully renewed in its overhaul. The Army favored this point of view in its administrative instruments. A helicopter was "defined" as a combination of identifiable components, each with a life history initiated at its last overhaul and terminated with each overhaul. The life history of an aircraft itself is also considered to begin and end with overhauls. For a survey of available analyses that supports this point of view, see Kamins (1970).

In spite of an admirable attempt to include costs in rates where the use considered appears to add additional costs, then, the flying hour cost program was a disappointment. The difficulties with administered prices, average fleet cost based prices, and insensitivity to variable marginal costs observed earlier existed here as well. In addition, the flying hour cost program exhibited inadequate understanding of the role of cost in making resource choices; irrelevant costs were included in prices and relevant costs did not appear. Once again, budgeting concerns appear to have played a larger role than cost concerns.

Appendix F

COSTS OF CHOOSING THE WRONG INPUT MIX

Two types of inefficiencies are important in thinking about cost minimization in large organizations comprising many individual activities. First, X-inefficiency in an activity means that the activity fails to produce as much as it could from any mix of inputs it chooses. That is, the quantity of production from the activity can be maintained while one input is reduced and no others are increased. Second, allocative inefficiency in an activity means that, although output can be maintained when one input is reduced only by increasing another input, the wrong mix of inputs is used to produce that level of output. That is, by changing the mix of inputs, it is possible to produce the output at a lower cost.

Both types of inefficiency are likely to exist in large organizations, especially when the products of activities in these organizations are not exposed to market tests. The more of either type of inefficiency we see in any activity, the more we are likely to see in the organization as a whole. However, we cannot simply aggregate from individual activities to characterize an organization. In particular, X-inefficiency in any activity implies X-inefficiency for the organization as a whole, but an absence of X-inefficiency does not. It is easy to show that only if the marginal value products of an input in all activities that use it are equal can X-inefficiency be avoided at the organizational level. As one would expect, the problems of possible inefficiency in a complex organization are themselves complex.

Measuring the costs imposed by these sources of inefficiency poses serious problems. Widely accepted measures of the cost of allocative inefficiency have been developed. Standard measures of the cost of X-inefficiency do not exist. Further, measures developed for allocative inefficiency implicitly assume that X-inefficiency itself does not exist. On top of all this, as we argue in the text, *both* sources of inefficiency probably stem from the same source in the Army—its disinclination and inability to respond to changes in input prices. Hence, it is unclear either how best to operationally separate the costs associated with these two types of inefficiency or how to measure them if we could.

The simplest way is probably to seek an estimate of the degree of substitution that *could* occur in the absence of the Army's difficulties

and simply set the degree of output growth (or input shrinkage) that could also occur aside. That is, hold X-inefficiency constant and see how allocative inefficiency varies as we vary input mix. This is the route we take below. It offers no way of suggesting what additional cost savings would result from eliminating X-inefficiency as well as allocative efficiency because it is next to impossible to separate these in practice. It presumably does, however, offer a lower bound on the cost associated with these two sources of inefficiency taken together.

In what follows, then, we implicitly assume away X-inefficiency and proceed to develop the standard measure of cost associated with allocation efficiency. The discussion proceeds in terms of an activity, but it could proceed just as easily at the level of Army aviation maintenance, the Army, or DOD as a whole. Of course, greater and greater aggregation subsumes more and more X-efficiency, making the measure offered here more and more conservative.

A STANDARD MEASURE OF COST

Suppose we have an activity that uses n inputs, ℓ_i, to produce an output, x, according to a production function,

$$x = f(\ell_i, \ldots, \ell_n) . \tag{1}$$

And suppose we wish to minimize the cost,

$$C = \sum_i w_i \ell_i , \tag{2}$$

where w_i is the wage of the ith input, of producing a given amount of this output, $\bar{x}$. Finally, suppose that the value of some factors, say ℓ_i, for i = 1, ..., k, are arbitrarily set at values $\bar{\ell}_i$. Then our problem is to minimize (2) subject to (1) and the constraint that $\ell_i = \bar{\ell}_i$, i = 1, ..., k. This produces a Lagrangean

$$L = \sum_{i=1}^{n} w_i \ell_i - \lambda [f(\ell_i, \ldots, \ell_n) - \bar{x}] = - \sum_{i=1}^{k} \phi_i (\ell_i - \bar{\ell}_i) . \tag{3}$$

This function achieves a minimum when

$$\begin{aligned} w_i &= \lambda f_i + \phi_i \quad \text{for } i = 1, \ldots, k \\ w_i &= \lambda f_i \quad \text{for } i = k+1, \ldots, n . \end{aligned} \tag{4}$$

We can use this information to determine how cost varies when we vary ℓ_i, holding output constant. First, totally differentiate (1) and (2):

$$dx = \sum_{i=1}^{n} f_i \, d\ell_i \tag{5}$$

$$dC = \sum_{i=1}^{n} w_i \, d\ell_i + \sum_{i=1}^{n} \ell_i \, dw_i \, . \tag{6}$$

Then multiply (5) by λ and substitute from (4):

$$\lambda dx = \sum_{i=1}^{n} w_i \, d\ell_i - \sum_{i=1}^{k} \phi_i \, d\ell_i \, . \tag{7}$$

Substitute (7) into (6):

$$dC = \lambda dx + \sum_{i=1}^{k} \phi_i \, d\ell_i + \sum_{i=1}^{n} \ell_i \, dw_i \, . \tag{8}$$

Holding x and w_i constant, we find that

$$dC = \sum_{i=1}^{k} \phi_i \, d\ell_i = - \sum_{i=1}^{k} (\lambda f_i - w_i) d\ell_i \, , \tag{9}$$

where λf_i is the marginal valuation of the last unit of ℓ_i consumed. Integrating (9) will give us the finite change in cost associated with changing ℓ_i. Hence

$$\Delta C = \sum_{i=1}^{k} \int_{\bar{\ell}_i}^{\ell_i^e} (\lambda f_i - w_i) d\ell_i \tag{10}$$

gives us the effect on cost of moving ℓ_i from $\bar{\ell}_i$ to ℓ_i^e, the level of ℓ_i at which $\lambda f_i = w_i$. As (4) indicates, ℓ_i^e is the cost minimizing level of ℓ_i. Equation (10) verifies this; $\Delta C > 0$ for any change in $\bar{\ell}_i$ that moves it away from ℓ_i^e. We can use (10) to measure the cost of setting ℓ_i at any level different from ℓ_i^e for any factor.

Equation (10) is most easily operationalized if we note that λf_i is the marginal value of the last unit of ℓ_i used; it is the height of the factor demand function for ℓ_i. Hence, (10) is simply the sum of the areas between the constant-output demand functions for ℓ_i, for each of the k inputs, and their wage levels for input levels between $\bar{\ell}_i$ and ℓ_i^e. It is a

sum of familiar "welfare triangles." Hence, if we linearize the demand functions—that is, assume a quadratic production function—we can approximate (10) as

$$\frac{1}{2} \sum_{i=1}^{k} \bar{\phi}_i \left(\bar{\ell}_i - \ell_i^e\right) \tag{11}$$

for $\bar{\phi}_i$, the value of ϕ_i when $\ell_i = \bar{\ell}_i$ for all $i = 1, ..., k$. Equivalently, this is

$$\begin{aligned} &- \frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} \partial \ell_i / \partial w_j \left(\bar{\phi}_i \; \bar{\phi}_j\right) \\ &= - \left[\frac{1}{2} \sum_{i=1}^{k} \sum_{j=1}^{k} a_i \eta_{ij} \left(\bar{\phi}_i / w_i\right)\left(\bar{\phi}_j / w_j\right) \right] \quad C \end{aligned} \tag{12}$$

for $a_i \equiv w_i \ell_i / C$ and $\eta_{ij} \equiv (w_j/\ell_i)(\partial \ell_i / \partial w_j)$, the constant-output cross elasticity of demand for ℓ_i with respect to w_j. Finally, by noting that for constant-output, $\eta_{ij} = a_j \sigma_{ij}$, where σ_{ij} is the partial elasticity of substitution between the ith and jth inputs, we can express the percentage effect on cost of varying ℓ_i from their cost minimizing levels as

$$\frac{\Delta C}{C} = - \frac{1}{2} \sum_{i=1}^{k} \sum_{i=j}^{k} a_i a_j \sigma_{ij} \left(\bar{\phi}_i / w_i\right)\left(\bar{\phi}_j / w_j\right) \quad . \tag{13}$$

(Cf. Harberger, 1974, pp. 76-79.)

If we are willing to deal with highly aggregated inputs, we can simplify (13): with two inputs, for example, (13) becomes

$$\frac{1}{2} a_i (1 - a_i) \sigma_{12} \left(\bar{\phi}_i / w_i\right)^2, \tag{14}$$

where $\bar{\phi}_i$ is the distortion in *relative* prices between the two inputs. The cost of this distortion depends on the inputs' cost shares, their substitutability, and the size of the price distortion itself. For example, consider an estimate of the cost of DOD's failure to respond to changing relative capital and labor prices over the period since World War II. Although the cost of labor relative to that of capital rose about

60 percent from the mid-1950s to the mid-1970s, little aggregate substitution occurred between capital and labor (Cooper and Roll, 1974). Suppose we attribute this lack of response to a failure to recognize the change in relative cost. That is, ϕ_i/w_i for labor is 0.6. If we assume DOD has an elasticity of substitution similar to that for the rest of the economy, $\sigma_{12} = 1$. Similarly, assume the cost share of labor is 0.75. Then, (14) tells us the cost of failing to respond is

$$= \tfrac{1}{2}(0.25)(0.75)(1)(0.6)^2 = 0.0338.$$

The failure to respond to a 60 percent relative rise in labor costs increases the costs of providing defense somewhat more than 3 percent. Table F.1 provides estimates under some alternative assumptions.

Table F.1

PERCENTAGE EFFECTS ON COST OF A 60 PERCENT RELATIVE PRICE DISTORTION

		$a_L : a_K$				
		0.1 : 0.9 or 0.9 : 0.1	0.2 : 0.8 or 0.8 : 0.2	0.3 : 0.7 or 0.7 : 0.3	0.4 : 0.6 or 0.6 : 0.4	0.5 : 0.5
σ_{LK}	0.5	0.81	1.44	1.89	2.16	2.25
	0.6	0.97	1.73	2.27	2.59	2.70
	0.7	1.14	2.02	2.65	3.02	3.15
	0.8	1.30	2.30	3.02	3.46	3.60
	0.9	1.46	2.59	3.40	3.89	4.05
	1.0	1.62	2.88	3.78	4.32	4.50

Several points are worth keeping in mind when using the values in Table F.1. First, other levels of distortion will lead to different cost responses. For example, a distortion of only 30 percent will have effects only a quarter the size of those in the table. Second, although we have used (14) to estimate effects on DOD as a whole, it could be used for any part of DOD. Other parts will be more or less labor intensive and have different opportunities to substitute between capital and labor. In general, labor's share will vary between 0.5 and 0.8; the elasticity of substitution will vary between 0.7 and 1.0. Hence, the table covers a broad range of possibilities. Relative price distortions, of course, can be greater or smaller than 60 percent. Third, although the percentage effects are small, absolute values of costs are great. For DOD, for example, with its $200 billion budget, each percentage point

represents $2 billion. Over a reasonable range of values for DOD as a whole, then, the costs involved here involve $5 to $8 billion. Fourth, the measure in (14) is only a partial measure and it becomes increasingly conservative at higher levels of aggregation. In particular, the $5 to $8 billion range for DOD as a whole is very conservative because it contains neither the costs associated with poor allocation of inputs across activities within DOD, which are likely to be substantial, nor the cost of any traditional X-inefficiency present within these activities. Even at a lower level like Army aviation maintenance, the measure used here is likely to miss substantial costs associated with X-efficiency. Finally, this measurement approach is obviously very crude. But when conservative cost estimates reach absolute levels of this magnitude, the measures suggest that substantial cost savings are lurking here somewhere.

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